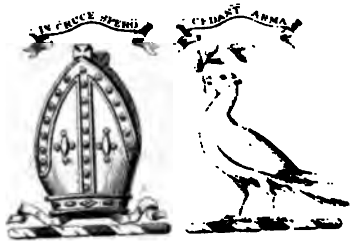
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PROCEEDINGS

OF THE

GEOLOGISTS' ASSOCIATION.

PROCEEDINGS

OF THE

GEOLOGISTS' ASSOCIATION.

VOLUME THE FOURTEENTH.

1895-96.

EDITED BY

A. MORLEY DAVIES,

A.R.C.S., B.Sc., F.G.S.

(Authors alone are responsible for the opinions and facts stated in their respective Papers.)

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CONTENTS.

NEW SPECIES DESCRIBED IN THIS VOLUME.

NOTE.—The pages on which the descriptions of these species appear were originally published on 21st July, 1896, as part of the pamphlet issued for the Long Excursion. Fuller descriptions of those marked * have since appeared in in vol. 50 of the *Monographs of the Palæontographical Society*. Fuller descriptions of those marked † are in print, and will appear during 1897, in the same publication; and those of the remainder will follow.

LIST OF ILLUSTRATIONS.

CORRIGENDA ET ADDENDA.

Page 48, line 15, *for* "ferovalis" *read* "perovalis."

„ 78, line 9, *for* "Silurian" *read* "Ordovician."

„ 83, line 10, *for* "have" *read* "has."

„ 182, line 2 from bottom, *for* "Greslya" *read* "Gresslya."

„ 184, line 17 from bottom, for "Spirifer" *read* "Spiriferina."

„ 203, line 17, *for* "Pecten, Valoniensis" *read* "Pecten Valoniensis."

„ 208, line 5 from bottom, *for* "Knole Castle" *read* "Knole House."

„ 211, line 9, *for* "Albums" *read* "Album."

„ 301, lines 25 and 26, *for* "Cytheridea Mulleri var." *read* "Cyprideis"; *for* "p. 42, pl. vi. fig. 12" *read* "p. 21, pl. ii. figs. 1*a*-1*i*; woodcut, fig. 2, p. 16"; *and for* "C." *read* "Cytheridea."

„ 314, line 16, *for* "Hencliff" *read* "Hen Cliff."

„ 355, line 5, *for* "J. J. Hamling" *read* "J. G. Hamling."

„ 364, line 11, *for* "Sowerby" *read* "Sorby."

„ 366, line 14, *for* "Streptorhyncus" *read* "Streptorhynchus."

„ 377, line 20, *after* "C. Barumensis" *add* "n.sp."

„ 388, *insert in Bibliography*:

1893, CHAPMAN, F.—"On Oolitic and other Limestones with sheared structure from Ilfracombe." *Geol. Mag.*, dec. iii, vol. x, pp. 100-104, pl. v.

Plate II., *for* "Mattelo" *read* "Matteli."

PROCEEDINGS

OF THE

GEOLOGISTS' ASSOCIATION.

Instructions for Binding Vol. XIV. of the Proceeding[s]

Plate I.	should face p. 30.	Plate X.	should face p. 29
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Mr. J. D. HARDY:—Waterslip Quarry; Ebbor Rocks; Wookey Hole; Cheddar Cliffs (all Carboniferous Limestone).

Rev. R. ASHINGTON BULLEN:—Section of unsorted Rubble Drift at Chesilton, Portland.

Rev. J. F. BLAKE:—Parallel Roads of Glenroy; Brora Coal-field (Oolitic); Storr Rock, Skye; Clam-shell Cove, Staffa; Giants' Causeway; Fingal's Cave; Dropping Well, Knaresborough.

Mr. A. M. HIDDON: — Beach, Port St. Mary, Isle of Man (Palæozoic beds with Quartz veins); Anvil Point, Swanage (Purbeck and Portland); Durlston Head, Swanage (the same); Shelly Cove, Bournemouth (Bagshots); Erratic Block, Norber, Yorks; Douglas Head, Isle of Man (Clay-slate); Scotch Rocks, near Blue Lobe, Mourne Mountains (Granite).

Mr. W. THOMAS:—Twelve photographs of views in the deep lodes of Dolcoath, Cook's Kitchen, and East Pool Mines, Cornwall, taken by the magnesium flash, and showing methods of working the ore, timbering the shafts and galleries, etc. (Photographed by Mr. J. C. Burrow.)

Mr. J. C. BURROW:—Twelve photographs of views in the Slate Mines of Llechwedd, Oakeley, Votty, and Bowydd, near Blaenau Festiniog, some open and some taken by the magnesium flash, and showing methods of working, etc.

Mr. E. LARDEUR :—Folkestone Sand Pit, Godstone, Surrey; Chalk escarpment, Caterham, Surrey; Iron-ore in Hythe beds, Tilburstow Hill, near Godstone; Triassic "dyke" in Carboniferous Limestone, The Vallis, Frome; "Swallow Holes" in Chalk, Purley, Surrey; Joints in hard Chalk, Purley, Surrey; Stalagmitic incrustation, Coombe Down Quarries, near Bath; Unconformity between Dolomitic Conglomerate and Old Red Sandstone, Clifton, Bristol; Unconformity between Inferior Oolite and Carboniferous Limestone, The Vallis, Frome.

Mr. PERCY EMARY :—Portland Bill; False bedding, Red Crag, Butley, Suffolk; Formation of boulders of syenite by weathering, Enderby, near Leicester; Small landslip of Carboniferous Limestone, Miller's Dale, Derbyshire; Marble rubbing bed, Hopton Wood Quarries, near Wirksworth, Derbyshire; Fissure in Lower Greensand, Ightham, Kent; Undercliff, near Ventnor, Isle of Wight; Section showing junction of Lower London Tertiaries with Chalk, Charlton; and several others.

Mr. HENRY PRESTON :—Views of the Hemlock Stone (Nottingham Excursion, Whitsuntide, 1892).

Contorted Chloritic Schists, near Valley, Anglesey; Caligula's Arch, a large natural arch near Rhoscolyn, West Coast of Anglesey; Irregular bedded and contorted drift deposits 1,100 feet high, lying above the Alexander Slate Quarries, Moel-y-Trifan; Violently contorted gneisses, grits, and schists of the South Stack series, near the South Stack Lighthouse, Anglesey; Glaciated rocks near the church, Barmouth (North Wales Excursion, July, 1892).

Hunstanton Cliff, showing Red Chalk (4 feet) at base of White Chalk and above Brown Carstone (Lower Greensand), the "sponge bed" (18 inches) being immediately above the Red Chalk; Alluvial Fan on coast of Norfolk, formed by rainwash down gullies in Drift Clay; Paramoudras, or pot stones, uppermost beds of Chalk, near Norwich; Large mass of Chalk-with-Flints in Drift, near Runton, Norfolk (cliff 120 feet high, chalk 500 feet long) (Easter Excursion, 1893).

The Needles, a large pinnacle of Quartzite near Howth, co. Dublin; Coast of Cambrian Quartzites, south side of Howth, looking towards Baldoyle; Trough of a large Synclinal Fold in Cambrian Quartzites and Shales, east of the Needles, Howth, co. Dublin; and a series of photographs of the alternating Ordovician Limestones and Shales from Donabate to Portraine, co. Dublin, illustrating the progress of brecciation by which the limestone bands have been broken up by pressure, squeezed out from their bed during folding, and carried into a stream of flowing shale (Long Excursion, July, 1893),

ORDINARY MEETING.

FRIDAY, DECEMBER 7TH, 1894.

GENERAL McMAHON, President, in the Chair.

The following were elected Members of the Association:— Miss Sydney Thompson; C. A. Loxton; W. L. Sclater, F.Z.S.; G. E. Ormiston; J. M. Coates; E. L. Fison; A. S. Kennard.

The following papers were read:—

"Note on Megalosaurian Teeth, discovered by Mr. J. Alstone in the Portlandian of Aylesbury," by A. SMITH WOODWARD, F.L.S., F.Z.S.

"Some Account of a Geological Excursion in Switzerland," by Prof. T. McKENNY HUGHES, F.R.S., HORACE W. MONCKTON, F.G.S., and Dr. W. F. HUME, F.G.S.

A large series of specimens in illustration of the papers was laid upon the table.

ORDINARY MEETING.

FRIDAY, JANUARY 4TH, 1895.

GENERAL McMAHON, President, in the Chair.

The following were elected Members of the Association:— H. J. Adams; G. E. Shaw; Frank Corner, M.R.C.S.; H. J. L. Beadnell; J. G. Gubbins; U. P. Swinburne; and Miss M. A. Reid, B.Sc.

Mr. G. F. Harris proposed the names of Mr. J. D. HARDY and Mr. JOHN HOPKINSON as Auditors, and of this the meeting approved.

A paper was read by Mr. G. F. HARRIS, F.G.S., on "The Analysis of Oolitic Structures," which was illustrated by the lantern.

Mr. DIBLEY exhibited a tooth of *Cestracion rugosus* from the Chalk of Warlingham, and a fine specimen of *Cidaris ornata* from Northfleet.

MR. UPFIELD GREEN exhibited some oolitic ironstone of Devonian age from Prünn.

THE BREAKING-UP OF THE ICE ON THE ST. MARY'S RIVER, NOVA SCOTIA, AND ITS GEOLOGICAL LESSONS,

By G. F. MONCKTON.

[*Read 1st December, 1893.*]

A STATEMENT of facts relating to the breaking-up of the ice on a large river in Nova Scotia may be of interest to those who, in the mild climate of England, have no opportunity of seeing such an event.

In Nova Scotia the extremes of heat and cold are greater than in England, and the rivers are often covered with ice more than a foot thick. The river to which my remarks refer is the St. Mary's River, the main stream of which has a length of about sixty miles. With its tributaries it drains about 600 square miles. At the head of the tide at Sherbrooke it has a normal discharge in spring of about 6,000,000 cubic feet per hour, and in summer 1,500,000 cubic feet per hour. It has a fall of about eight feet to the mile just above that point.

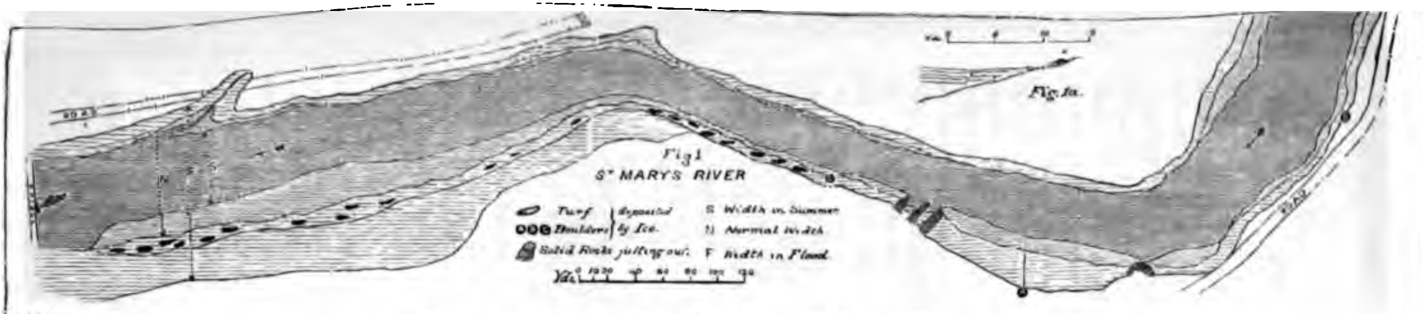
This year it was colder than usual. The thermometer, which rarely falls lower than 5° below zero, fell on several occasions to ten, and on two occasions to eighteen degrees lower. The ice, therefore, was thicker than usual and only broke up twice. Usually it breaks up and goes out to sea three times. Some of it, however, just previous to the second break, having broken, floated down and caught under the solid ice below the Sherbrooke Bridge. Here it may be mentioned that once in every few years the ice above, having broken before the solid ice below Sherbrooke, has caught against the solid sheet and dammed up the waters, flooding some one hundred acres, and depositing on them large quantities of boulders and gravel. The ice-cakes have on these occasions done great damage, forcing wooden barns and other buildings off their foundations and pushing them through the shallow water into the river current. In the year 1881 the river was raised in this manner fifteen feet above its usual level.

Ice, in these rivers, is formed at first at the bottom, round stones where the current flows slowly. As the piece grows it lifts the stone off the bottom and floats it away. When this anchor ice, as it is called, is coming down in quantity it accumulates in the eddies, and, freezing into large cakes, soon gives rise to a solid sheet across the river at that point. The ice, therefore, at such points is very thick, and may hold the rest back for some time if it breaks above this point.

On February 12th, during a thaw, all the ice on the river for three miles above the bridge broke and came down. It broke off in portions from 100 to 500 yards long, and as there was an interval between the breaking of each of these lengths, each one had time to jam and back up the water before the next portion floated down. Part of each of these lengths would thus be floated over the one in front of it. In many places two, three, and even four cakes were lying on one another, each a foot or more in thickness. There was not much water in the river on this occasion, but the jam of ice raised it at the bend six feet in two hours. In one place ice cakes were floated on to the road eight feet above the ordinary spring water level. The shock of these ice-fields, 200 feet wide and 300 yards long, was very great, especially as most of the ice came down in unbroken cakes 15 to 200 feet square, the largest being, of course, the thickest. When the ice could not be driven far forward it sought relief by lateral expansion, the cakes sliding up the bank above the water. What force these had may be realised from the fact that they totally destroyed at one blow a stone wall, the bottom of which was composed of two rows of stones, each two to eight cubic feet in bulk. They also pushed up the bank boulders and trunks of trees which had been stranded there previously. At one point the ice deposited a boulder of six cubic feet at the top of the bank. Whence this boulder came does not appear. There is no place near from which it could have come unless it was pushed up out of the river bed, which is not likely, as the river was very deep here and the lower part of the banks very steep. The most likely supposition is that it was floated down from a point a mile away, stranded near the top of the bank, and pushed up the rest of the way by cakes sliding up the bank. As the weight of it would be about 850lbs. seven cubic yards of ice would have sufficed to float it down. It might have rolled down the bank on to the ice, having been worked out of its place by the frost. In studying the river for three winters I have had many opportunities for observing this. The crack, which is the only separation between the parent rock and a block of stone, will, if the water rises over it occasionally, be sometimes widened to a fissure nearly an inch wide, in a year, by the expansion of the water in the crack. Having once reached a width of two or three inches it will be rapidly widened by pieces of wood and roots of trees floating down at high water becoming entangled in the cracks. These act as powerful levers. If the position of the stone is favourable it will then soon slide out of place. On one of the rocks marked in the plan (Fig. 1, p. 7) is a stone containing thirty cubic feet, which three years ago was only separated on two sides by cracks from the parent rock, three sides being unprotected. Now on one side is a fissure six inches wide, on another a fissure two inches wide. In this case the rapidity of the opening

of the fissure is partly due to a tree having caught by one of its branches in it last year.

Near this boulder another one of a cubic foot was left by the ice. One hundred yards higher up the river there is a boulder weighing five tons lying half-way up the bank. It is said that this rock was originally pushed up by ice out of the river. I cannot vouch for this, but it was certainly moved a little this year, one end being turned up the bank a little farther. As it lies on other loose stones this was comparatively easy. There is also a third boulder (*c*), which was left half-way up the bank by the ice. I think this was pushed up, as the water rose from a point lower down the bank. It contains about four cubic feet. Usually the ice goes out to sea within a few hours of its having broken up, but on this occasion it was held by the solid ice below until the water had fallen, and, therefore, some of the cakes were stranded along the bank and melted there. It is difficult to make any computation on a boulder-strewn bank as to the amount of gravel and boulders deposited by the ice, but turf can be easily distinguished. The river having sunk to its normal level in April, I went over the ground and estimated the quantity of turf and boulders lying on it in a space marked in the map (Fig. 1, p. 7). Much of the ice which stranded there had floated off without melting, and that which melted there amounted to about 7,000 square yards. Owing to the steepness of the banks in other places this strip, 1,400 feet long and 40 feet wide, was the only part where much ice was left. The turf and gravel lying thereon amounted to about 808 cubic feet. Some of this turf was in strips ten or fifteen feet long and four or eight feet wide, having an average thickness of six inches. The state of the banks for the first half mile above showed that not more than one-tenth could have been derived thence, and as, above that, the banks are of rock for nearly two miles, most of this must have been floated from the meadows above. Great damage is done to these meadows every year by the ice. The ice covering a portion of this river forty miles long, or about 3,560,000 square yards in all, usually floats out to sea in the spring freshet; and also in a thaw which occurs once or twice every winter, a length of about fifteen miles, or 1,350,000 square yards more, floats out to sea. Supposing that all this ice carried the same proportion of turf and stones upon it—a fair assumption, since in the shallow, slower waters, higher up the river, it would have more opportunity of getting these than in its course between rocky banks below—it would carry out with it 550,000 cubic feet, besides the fine sand in suspension and the stones rolling along the bottom. When this figure is compared with the total area drained, it seems but a very small amount, being only $\frac{1}{2546}$ of an inch in thickness for the whole 600 miles, but it must be remembered that this material is in reality drawn from an area not exceeding fifty square miles, the matter removed by the



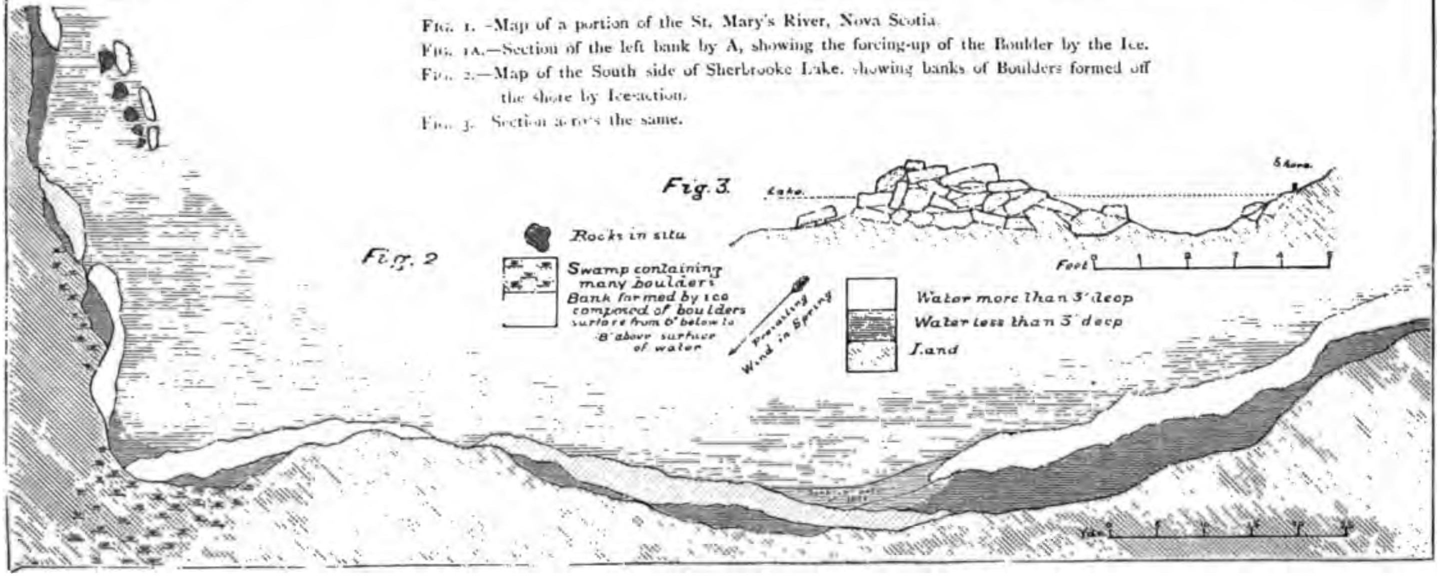


FIG. 1.—Map of a portion of the St. Mary's River, Nova Scotia.

FIG. 1A.—Section of the left bank by A, showing the forcing-up of the Boulder by the Ice.

FIG. 2.—Map of the South side of Sherbrooke Lake, showing banks of Boulders formed off the shore by Ice-action.

FIG. 3. Section across the same.

ice of the small brooks and of the main stream itself for twenty miles, being carried down the river as fine suspended sand or gravel at the bottom of the river bed.

The anchor ice, too, which may be heard grating against the solid ice sheet as it floats down, must carry away a good deal. When the river was not quite frozen over, I have seen in an opening three feet wide, where the swiftest part of the current would be, three pieces of this anchor ice, averaging nearly a cubic foot each, float down every minute. Such pieces would be able to carry earth and stones weighing more than three pounds each. And if they continue drifting in the same quantity after the river is completely frozen over, which I should judge to be the case by the sound, 4,320 such pieces would pass down this narrow strip of swift current every twenty-four hours, and these would carry nearly six tons. If, however, they were laden only in the same proportion as the ice which melted at Sherbrooke, they would carry only 38 cubic feet or about 4,000 pounds. As the river is frozen for three months, this ice could remove during this period 180 tons, or 3,800 cubic feet. Of course there would also be large quantities of anchor ice drifting down in the slower current in the remaining width of 180 feet of the stream, probably twenty times as much.

The ice cakes greatly assist the water in carrying away gravel. I have seen them often, when caught in a jam, standing up on end out of the water, and being dragged in that position several yards. In this way they cut deep furrows, the material from which is at once swept away. There are now to be seen in the bed of the river some of these furrows twenty yards long and more than a foot deep. The current of this river, as it flows at the rate of one and a-half miles, would be able to roll stones one inch in diameter (according to Geikie). The bays, in the spring, are often full of the anchor ice, previous to the breaking of the ice on the rivers. The stones in the anchor ice striate rocks on the shore. The large lakes are bordered with ridges of stones (Figs. 2 and 3), usually at a distance of from one to three yards from shore, which, lying in shallow water, have been forced nearer the land by the expansion of the ice. I think these stones are deposited first in the shallows by anchor ice coming down the brooks. The drifting of the ice on the lake after it has broken also pushes the stones into ridges. The reason that they do not come nearer the shore is probably that the shallow water between them and the land, having frozen very hard, prevents it, as it does not melt till later in the season. They are not continuous, but occur chiefly in the coves at the edge of deep water.

The small brooks are greatly assisted in their work of erosion by the freezing of the ground to a considerable depth. During the winter the brooks are covered with a thick coating of ice,

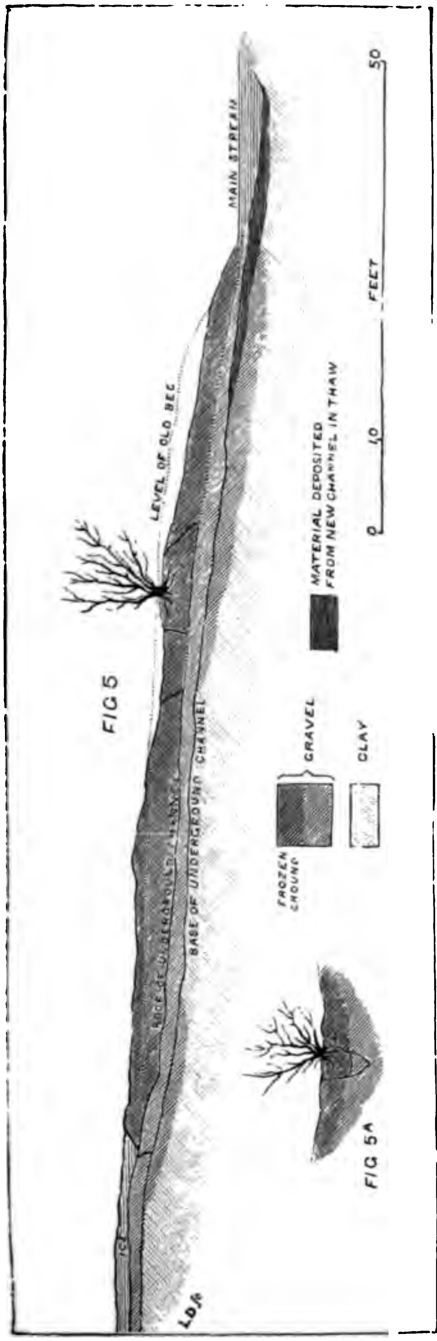


FIG. 5.—Section along new channel, second day of thaw.

5A.—Section across the same.

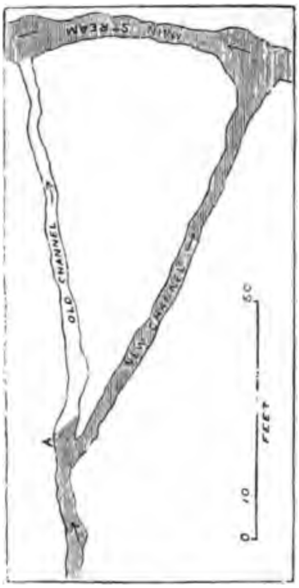


FIG. 4.—Brook confined under ice excavating new channel.

A. Dam of stones and silt, formed under ice.

and the water, by rolling down gravel, gradually dams itself at a shallow place. Unless it can then flow over its icy covering it must find a new channel. By percolating under the frozen ground it cuts a new passage two or three feet below the surface, and when once the water flows through this in a continuous stream the pressure behind gives it considerable force, and it is enabled to rapidly enlarge the new outlet. When a thaw comes the ground above falls in and is swept away. I have seen a small brook, whose old outlet was thus damned, open a new channel by this means thirty yards long, eight feet in cross section, in four days (Figs. 4 and 5). The undermining had been done unnoticed, the brook appearing to have no outlet during the frost. It deposited at its mouth a delta containing about 100 cubic feet, the remaining 600 cubic feet being swept down the stream into which it flowed. This same brook, on another occasion, cut a new channel twenty yards long, fifteen feet wide at the top, and three feet deep, in one winter. The material, in this case, was soft, and would not stand in steep banks. These operations are greatly assisted by the work of man in cutting away the trees, the oots of which bind the ground together.

ON THE DISTRIBUTION AND RELATIONS OF THE WESTLETON AND GLACIAL GRAVELS IN PARTS OF OXFORDSHIRE AND BERKSHIRE.

By HAROLD J. OSBORNE WHITE, F.G.S.

(Read 4th May 1894.)

IN the following communication I propose to give some account of two important Gravels, well represented in a district that I have had opportunities of examining during the past few years—noticing more particularly those features which appear to be of interest as indicating their mode of origin, and their general relations.

The works dealing with the Drift Geology of the district are not numerous, but at the outset I must acknowledge my particular indebtedness to the writings of Professor Prestwich.

I have also to thank Mr. Monckton, both for the assistance I have received from his papers, and the personal encouragement he has accorded me; and Mr. Llewellyn Treacher, of Twyford, for the local information with which he has kindly furnished me at various times.

The area to which attention is directed is, from the distribution of the deposits to be discussed, somewhat irregular in form, but may be taken to include that portion of Oxfordshire lying to the east of the escarpment of the Upper Chalk, and the adjoining portion of Berkshire, bordering the Thames between Streatley and Cookham. (See Map, Plate I.) On inspecting the Geological Survey Map (Sheets 7 and 13) it will be seen that over the greater part of this area the Chalk is exposed at the surface, though the Tertiary strata, which come on in the south, are also represented by numerous outliers. The country has a general inclination to the south-east, corresponding with the dip of the beds, but the uniformity of the slope is much broken by the broad valley of the Thames, by the numerous branching, steep-sided coombes—so common a feature in the more elevated Chalk regions—and, to a less degree, by the somewhat abrupt rise in the ground that takes place where the Chalk is covered by the outlying masses of sands and clays of Lower Eocene age.

Before dealing with their distribution it will be, perhaps, as well to describe the general composition and character of the two gravels, and to indicate the more important distinctions existing between them in this part of the country.

The older, or Westleton Gravel consists essentially of pebbles of flint and of white vein-quartz, with which are associated a variable proportion of sub-angular flints, together with pebbles of lydian stone, quartzite, and of other rocks foreign to the district, all of small size. In places where these materials occur in sufficient quantity to form workable deposits of gravel they are usually embedded in a light-coloured quartzose sand ; but they are frequently found scattered throughout the loam or clay forming the surface soil to a depth of a few inches or feet. In either case the disturbed condition of the gravel, and the obvious connection often existing between its position and the contours of the neighbouring ground, plainly indicate that it has suffered some re-arrangement since its original deposition.

Within the present area this gravel occurs either in the form of small disconnected patches upon some of the Tertiary outliers between 650 feet and 450 feet above O.D., or as thin spreads extending over certain parts of the higher Chalk ground. It is best developed in the former case.

In employing the term "Westleton" for this gravel, I have followed Prof. Prestwich, who, in 1890, described it as occurring at five localities within this district under that name.* Whatever objections it may be open to, the name is at least a convenient one, and, moreover, has a specific value not possessed by the alternative appellation of "Pebbly Gravel," used by the Survey.

The second division of the gravels, to which the term Glacial is applied in Mr. Whitaker's *Geology of London* (1889, vol. i, p. 300), and which is distinguished in the published Drift maps by a pink colouration, has the following general composition, the more abundant materials standing first on the list:

1. Angular and sub-angular flints;
2. Flint pebbles ;
3. Vein quartz, the larger specimens being usually in a less worn condition than the smaller ;
4. Reddish, brown, and grey quartzites, much worn and ovoid in form ;
5. Well-worn pieces of yellow, brown, and red sandstone, frequently micaceous ;
6. Angular Sarsen stones ;
7. And, lastly a variety of specimens of less common occurrence, such as pebbles of dark veinstone, basanite, chert, compact grit, ironstone, etc., and, very rarely, of igneous rocks.

The propoition and condition of the constituents are subject to considerable variation, and the sand with which they are associated also varies both in quantity and quality.

As will be seen from the above short description, the composition of this gravel should, even in the absence of other evidence,

* "On the Relation of the Westleton Beds to those of Norfolk, etc., etc.," Part II, *Quart. Journ. Geol. Soc.* vol. xlvi 1890.

enable one to distinguish it from the Westleton Gravel. Its generally angular condition is in marked contrast with the pebbly condition of the latter, and both the size and the variety of the rocks represented much greater. The red and brown quartzites above mentioned (which are derived from the Bunter pebble beds of the Midlands) form one of the most characteristic features of the glacial gravels of the London Basin, and are sometimes so numerous as to constitute one-half of the deposit. The absence of these materials in the Westleton Gravel is regarded by Prof. Prestwich as a further means of distinguishing that deposit from the Glacial Gravel. That the distinction is one of value there can be no doubt, but it must be mentioned here, and it will be shown later on, that the Westleton Gravel is not wanting in quartzites that bear an extremely close resemblance to those of the Glacial Gravel.

In its distribution, too, the Glacial Gravel differs considerably from the Westleton. The area it occupies is much more extensive, and, at any given locality in this district, it is invariably found to occur at lower levels than the latter. Although it may be met with in isolated patches it more typically forms wide-spread sheets between 200 and 500 ft. above O.D.

THE DISTRIBUTION OF THE GRAVELS.

It will be convenient to consider the Oxfordshire and Berkshire portions of the area separately.

I.—OXFORDSHIRE.

In Oxon the Westleton Gravel is represented on the Tertiary outliers of Upper Assendon, Nettlebed, Stoke Row, and Greenmoor Hill, and on the Chalk at Witheridge Hill, and around Checkendon, and Ipsden Heath—all of which localities are situated on the high ground forming the south-western end of the Chiltern Hills.

Upper Assendon.—The steep slope rising immediately to the east of the village is crowned, at a height of about 600 ft. O.D., by a thin capping of the Reading Beds, in the loamy soil of which there occur scattered pebbles of flint and white quartz. The deposit is a mere remnant, but there can be no doubt as to its Westleton affinities.

The neighbouring outliers of Turville Common and Maiden Grove, at a rather greater elevation, are apparently devoid of Westleton Gravel.

Nettlebed.—The very shingly gravel of this interesting Tertiary outlier has been too recently described in your Proceedings, and elsewhere,* to necessitate any detailed account of it

* Prestwich *op. cit.*, p. 140; Monckton and Herries, "On Some Hill Gravels North of the Thames," *Proc. Geol. Assoc.*, vol. xii (1891), p. 112; the author's "Notes on the Westleton Beds near Henley-on-Thames," *Ibid.*, p. 382; J. H. Blake, "Report of Excursion," *Ibid.*, p. 205.

being given here. It consists of flints, in both a completely rounded and sub-angular form, and small pebbles of quartz, in a matrix of white sand or sandy clay. Other materials are extremely rare. The bulk of the gravel rests on the west and north slopes of the hill, at an elevation of rather more than 650 ft. O.D. —the greatest height at which the Westleton Gravel is known to occur in the London Basin.

Witheridge Hill.—On the steep slope at the southern end of this hill, at about 460 ft. O.D., there is a pebble gravel, consisting of rounded and somewhat angular flints, quartz pebbles, small pieces of dark chert and grit, in a light sand, resting on the Chalk. Its characters are distinctly Westleton, but its position and low elevation render it certain that it is only a reconstructed deposit.

Stoke Row.—South of this village there exists an outlier of sand and mottled clay of the Reading Series, which has been considerably worked for bricks. In the numerous sections exposed the Eocene Beds are seen to be overlain by a pebbly gravel, whose composition proclaims it to be the Westleton Shingle of Prof. Prestwich. As its existence does not appear to have been noticed by that authority, and I have not been able to discover any mention of the deposit, a short description will not be out of place here. The materials of which the gravel is composed are—

1. Black and white flint pebbles;
2. Pebbles of white and pink quartz (up to 1 in. diam.);
3. Sub-angular and angular flints, many of which are of the tabular variety (to 12 in. diam.); and
4. Small, dark lydian stones.

The rarer constituents are—

5. Sub-angular pieces of dark chert;
6. Pale coloured and small red quartzites;
7. Sub-angular sarsen-stones (to 12 in. diam.);
8. Pebbles of various kinds, sandstones, grits, etc.

The reddish quartzites, though of small size, are apparently identical with those so abundant in the neighbouring Glacial Gravel.

At the highest part of the hill (about 570 ft. O.D.) the deposit is thin and much mixed up with the loamy soil, but on the gentle incline to the north it thickens, and it is here that the best sections are to be seen, at a height of about 550 ft. O.D. The average thickness is not more than three feet, but in a pit a few yards to the east of the road to Kingwood Common, and close to the village, its depth increases suddenly to 15 ft., and its base is not shown. The gravel evidently occupies a pipe-like hollow in the disturbed Reading Beds. Similar pipes, though on a smaller scale, occur at Nettlebed on the line of the fault crossing that outlier.

The gravel is mixed with red, ochreous sand, and becomes coarser towards the bottom of the pit. In another excavation, a short distance to the east, the gravel is thin, and indistinctly bedded with clay and loam, and rests on brownish sands containing seams of angular and pebbly flints which, in turn, overlie an irregular surface of Reading Sands.

A thin layer of the Westleton Gravel in a reddish loam covers the north-western slopes of the outlier and extends on to the adjoining Chalk.

Checkendon.—Messrs. Monckton and Herries* have recorded the existence of a patch of gravel with white quartz pebbles in a small wood, a little south of Checkendon Rectory, 600 ft. O.D.

The gravel referred to is unquestionably Westleton, and possesses the following composition—

1. Flint pebbles;
2. White quartz pebbles;
3. Sub-angular and angular flints;
4. Pebbles of dark chert, and lydian stone;
5. Small yellowish and reddish quartzites—

in a matrix of brown loam.

The deposit, which closely resembles that of Stoke Row, is not however confined to this one locality, but occurs in patches over a tract of high ground between Checkendon and Ipsden Heath, resting directly upon the Chalk. The pebbles are, more often than not, scattered through the clay-with-flints, but they are occasionally numerous enough to form thin, though distinguishable, masses. Even where best developed the gravel is evidently not in its original position.

Greenmoor Hill.—The Tertiary outlier, of which this hill forms the highest portion, has a capping of pebbly gravel which has been described as a "well-defined bed of Westleton Shingle" by Prof. Prestwich,† who also assigns it a composition rather similar to that of the Stoke Row gravel, described above. That the deposit should be classed as Westleton there can be little doubt, but I am not in accord with Prof. Prestwich on the question of the proportion of the materials constituting it. Messrs. Monckton and Herries, in their paper "On Some Hill Gravels North of the Thames" (*loc. cit.*, p. 113), while speaking of this deposit, remark that "it is not of the ordinary type of Westleton Shingle," and I quite agree with them.

The proportion of large, white-coated, sub-angular and angular flints is exceptionally large, and appears to equal that of the flint pebbles; while the white quartz pebbles are certainly less abundant than in other Westleton deposits of the district. Other rocks are apparently absent. It is of interest to remark that, in its composition, this gravel approaches the type of Southern Drift noted by

* *Op. cit.*, p. 113.
† *Op. cit.*, p. 141.

Mr Monckton in the Silchester district, some miles to the south.*

Close to the inn at the top of Greenmoor Hill (600 ft. O.D.) there are sections three or four feet in depth, showing the gravel —which has evidently been much disturbed—embedded in a brown sandy clay derived from the Reading Beds below.

The Glacial Gravel of the part of Oxfordshire here dealt with appears to be confined to an area whose northern and southern boundaries respectively correspond, more or less closely, with the 500 foot contour, and the valley of the Thames. The country to the north of this area rises steadily to within a short distance of the sharply defined escarpment of the Upper Chalk, certain tracts attaining elevations of between 700 and 800 ft. O.D. A large proportion of this high Chalk ground is covered with the clay-with-unworn-flints, but—with the exception of the Westleton patches before described—other drifts are absent.

In the east of the district, near the Oxon-Bucks county boundary, the Glacial Gravel covers much of the heights overlooking the Thames, and gives rise to small plateaux, of which No Man's Hill (315 ft. O.D.), to the north of Henley, is a good example. About the village of Fawley (490 ft. O.D.), in Buckinghamshire, a mile north of, and connected with the above, a flat-topped ridge is covered with a deposit chiefly consisting of angular flints in brown loam; but the red quartzites and other rocks from the Glacial Gravel frequently occur also.

To the west of the deeply-cut Assendon Valley this gravel forms deposits of more importance. The village of Bix stands upon a plateau ridge, extending from the neighbourhood of Lower Assendon towards Nettlebed Woods, and possessing a gentle slope in that direction. The gravel which caps this ridge is shown in section in the lane connecting the two former places (at about the 400 foot contour). It is somewhat pebbly, and associated with sand and reddish loam. North-westward, near the 500 foot contour, there is a decided rise in the ground, and the gravel gives place to the loam with white angular flints of Nettlebed Woods.

The Glacial Gravel is well represented to the South of Bix, in Lambridge Wood, and over the more open tract between that place and Badgemore, above Henley.

Near the northern end of Lambridge Wood, and rather above the 400 foot contour, there are some shallow pits showing a few feet of yellowish and reddish sandy clay, overlain by a coarse gravel containing an abundance of the typical red and grey quartzites, together with little-worn flints, quartz grits, micaceous sandstone, and dark vein- or lydian stone. The materials are rather above the average size of those occurring in this part of the district, and

* "On the Gravels South of the Thames from Guildford to Newbury." *Quart. Journ. Geol. Soc.*, vol. xlviii (1892), p. 37.

I found one specimen of quartzite with a maximum diameter of 8 inches. This deposit seems to lie in a shallow depression in the Chalk.

Between the Assendon and Harpsden valleys wide spreads of Glacial Gravel form well-marked plateaux, or terraces, rising from the neighbourhood of the Thames, north-westward, in broad steps, the most marked of which roughly coincides with the 300 foot contour. Sections at about that elevation are to be seen in the road cutting S.W. of Herne's Farm, and on Peppard Common.

The gravel is generally loamy, and varies much in fineness.

A pit on the north side of the road from Gray's Green to Shepherd's Green shows about 10 feet of red-brown sand (much like that of the Reading Beds), succeeded by a thin layer of gravel with red quartzites, ironstone, etc., passing up into clayey soil. The height of this pit is a little above 400 ft. O.D.

In the wood south-east of Highmore Cross (460 ft. O.D.) there is a good section, showing 9 feet of reddish-brown sand, with current-bedded seams of red quartzite gravel, which is fine above and moderately coarse below, the materials in the latter case ranging up to 6 inches in diameter.

South-west of Highmore Cross the Glacial Gravel occurs at about the same height (450 ft. O.D.) as, and is only separated by a small valley from, the rearranged Westleton deposit of Witheridge Hill: while at a short distance to the north, near Highmore Common (500 ft. O.D.), it dies out and is replaced by a drift of white angular flints in loam, as at Nettlebed Woods.

Between the upper branches of the Harpsden Valley an inclined ridge extends from Crowsley Park (240 ft. O.D.), north-westwards, to the wooded eminence formed by the Eocene outlier of Stoke Row. The Glacial Gravel which caps this ridge is only shown in road cuttings near the former place, but at Shiplake Hill (about 340 ft. O.D.) there is a good section of about 15 ft. of gravel, with which are interbedded seams of reddish, ochreous sand, and loams. Near the top the constituents are fine and mixed with the loam; lower down they are coarser, and the loam and sand are in distinct beds. Flints, in all conditions, are very abundant, and the red quartzites are common — the largest specimens of the latter being about 6 inches in diameter. Quartz and sarsen-stone also occur, and one rounded block of sandstone I saw was 12 inches in length.

At Kingwood Common (400 to 450 ft. O.D.), a mile to the north-west, the gravel thickens out to an important mass, whose broad, flat surface forms a striking feature in the landscape. I could find no good section, but I think that this deposit must exceed 20 feet in depth.

A shallow valley skirts the plateau formed by this mass on the north-west, and separates it from the rising ground on which

Stoke Row stands, though traces of Glacial Gravel occur on the latter up to within a short distance of the 500 foot contour.

In the country to the west of the above localities the Glacial Gravel occurs in even more extensive sheets. The most important of these extends from Kidmore End (300 ft.), north-westward, to Hook End (500 ft.), and includes Sonning Common, and Cane End. Over this area sections are scarce; but the wide, flat stretches of gently inclined ground, the extremely stony nature of the soil, and many other minor features testify to the existence of thick masses of gravel below. These features become more marked on the north and west, implying an increase in thickness of the gravel in those directions. At about the 500 foot contour, near Exlade Street, this gravel, is, as usual, lost; the more sharply rising ground beyond bearing only clay-with-flints and washings from the older, pebbly gravel of the district.

Farther to the west, in College Wood (400 to 500 ft. O.D.), and at Goring Heath, to the south (300 to 400 ft. O.D.), the Glacial Gravel is again abundant. Near the latter place one of the finest and most interesting sections of this gravel in Oxfordshire is to be seen in a roadside pit, at a height of about 360 ft. (The exact spot is at the top of the "F" of Charity Farm, on the new 1-inch Ordnance Map, No. 268.) The excavation has been carried to a depth of 20 feet or more, and the gravel thus exposed evidently occupies a large pipe in the Chalk, which is visible at various levels round the sides of the pit.

The gravel is composed of—

1. Red and grey quartzites, of all sizes up to 12 inches in diameter;

2. Large flints, mostly sub-angular or unworn ;

3. Abundant large blocks of sarsen-stone—the largest I have found measuring 18 by 18 by 8 inches ;

4. Sub-angular pieces of vein-quartz, up to 12 inches in diameter ;

5. Dark vein- or lydian stones, up to 6 inches diameter—

in a matrix of ochreous sand.

Next to the large size of the constituents—many of which are veritable boulders—the most remarkable feature of the deposit is the abundance of the quartzites. Throughout the region dealt with in this paper it is usually found that flints, in one form or another, make up the greater part of the Glacial Gravel, but here they are actually equalled, or even excelled in number by the rounded blocks of Bunter quartzite.

Unusual as the character of the gravel in this pit may seem to be, there is reason to believe that it to some extent represents the type of Glacial Gravel prevalent in the neighbourhood; for although excavations are, unfortunately, rare, one cannot help being struck by the great proportion and the large size of the red quartzites

among the stones that everywhere strew the fields, in spite of the continued clearing the ground is subjected to by its owners.

Still farther westward, through the convergence of the Thames Valley and the high ground near the Chalk escarpment at the western limit of the district, the Glacial Gravel becomes restricted to the higher and less inclined portion of the northern slope of the Pangbourne-Goring gorge, where it forms a terrace less than a mile in width, between 400 and 500 ft. O.D. Its coarse character is here maintained.

Thus far, the larger and more elevated masses of Glacial Gravel in this part of Oxfordshire have been chiefly dealt with, and it still remains to give some account of the lower deposits bordering the Thames. In doing so it will be convenient to follow them from west to east.

Between Goring and Mapledurham the descent into the valley from the high ground on the north is very steep. Along the crest of this slope the Glacial Gravel occurs at heights of between 300 and 400 ft. From Mapledurham to Caversham the valley slope, though still steep, is of less height, and the ground behind it, from about 320 ft. O.D. at the small Reading outlier of Chazey Heath, and that near Whittle's Farm, on the north, down to 230 ft. O.D. (about 110 ft. above the Thames), on the crest of the slope, is everywhere covered with gravel of the ordinary composition in alternating beds of fine and medium texture, attaining in places a depth of 15 ft. How much of this gravel is to be classed as Glacial it is, however, hard to decide. From the pits near Toot's Farm (114 ft. above the Thames), a large number of palæolithic implements and flakes, resembling those found in the river terraces in the neighbourhood of Reading, has been obtained during the past few years by Dr. Stevens,* and other local collectors. An intelligent workman informed me that he had found implements of a similar character in the pit one-third of a mile north of Blagrave's Farm, about 270 ft. O.D. It is therefore tolerably certain that, in spite of its height above the recognised terraces of the Thames, much of this spread belongs to the deposits of that river.†

The Tertiary outlier of Emmer Green, north-north-east of Caversham, has a well developed covering of Glacial Gravel, good sections of which occur at the brickyard (279 ft.). The deposit is sandy, varying in thickness from 3 to 10 ft., and red quartzites and vein quartz up to 3 inches in diameter are abundant. Mr. George W. Smith, of Reading, has found two palæoliths in the "Black Horse" pit, near this place, and about

* See his paper "On the Earliest Known Traces of Man in the Thames Drift at Reading." *Trans. Berks. Archæol. and Architect. Soc.*, 1881-1882. Also O. A. Shrubsole, "On the Valley Gravels about Reading, etc." *Quart. Journ. Geol. Soc.* Vol. xlv (1890), p. 582.

† I may add that the mode of occurrence of the implements in the undisturbed and well stratified gravel is such as to leave no doubt that they were laid down contemporaneously with that drift.

270 ft. O.D. The larger neighbouring outlier of Binfield Heath (300 to 320 ft. O.D.), and the Chalk country closely adjoining it on the north and north-east, are also overlain by drift of the same character, which can be seen resting irregularly upon the outcropping edges of the mottled clays and sands of the Reading Beds in the road-cutting at Shiplake Row. Mr. Treacher has recently called my attention to the presence of a small proportion of Greensand chert in the pits about a quarter of a mile distant to the north-west (*cf.* the Harpsden deposit, *infrâ*).

North of the village of Shiplake, the Thames Valley Gravel extends continuously up the slope to the 200 foot contour. Here, and at other places farther down the Thames where the slope to the river or its recent plains of alluvium is more gradual, there would seem to be a direct passage of the Glacial into the higher terraces of the River Gravel; and in the absence of lithological differences, the difficulty of separating the one from the other becomes very great.

In Harpsden Wood (220 to 240 ft. O.D.) there occurs a gravel of a type extremely uncommon on the Oxfordshire side of the river. Its composition is as follows—

1. Angular and sub-angular flints, a few of which are green-coated;
2. Numerous sub-angular pieces of brown Greensand chert (up to 1½ in. diameter);
3. Small flint pebbles;
4. Small pebbles of white quartz;
5. Occasional pebbles of red quartzite, and other rock-fragments from the Glacial Gravel.

These materials, associated with yellow sand and loam, form a thin deposit of limited extent, passing north-westward into a plateau-forming deposit of what may be equally well described as Glacial, or high terrace River Gravel. The large proportion of chert—a material characterising so much of the Southern Drift and its derived gravels south of the Thames—is an interesting feature of this deposit, and one to which I shall have occasion to refer before concluding this paper.

Between Harpsden and Henley no distinction can be made between Glacial and River Gravel, for the northern slope of the Thames Valley here being gentle, the former passes down insensibly into the latter. Messrs. Treacher and G. W. Smith found palæoliths so far distant from the river as Highlands Farm (? about 270 ft. O.D.).

The gravels on the opposite side of the Thames now claim attention.

II. Berkshire.

In the portion of this county here dealt with, the Westleton Gravel is represented at Bowsey and Ashley Hill on the east, and,

doubtfully, at Common Wood, near Streatley on the west. As the two first mentioned localities are in close proximity, and their respective deposits of similar character, it will be convenient to consider them together.

Bowsey and Ashley Hill.—The pebbly gravel capping these important London Clay outliers has already been described in your Proceedings,* but in order to bring out more clearly certain features of importance in the present juncture, it will be necessary to give some further account of it.

The gravel, which is considered by Prof. Prestwich to be of "characteristic Westleton type,"† is composed of pebbles of flint and white quartz, and sub-angular flints, together with some light-coloured quartzites, quartz grits, sandstones, pebbles of lydian stone and dark chert, occasional fragments of Greensand chert, blocks of sarsen-stone, and, lastly, a variety of rarer rock specimens—in a yellow sand or loam.

On Bowsey, this gravel occurs as a few separated though well-marked patches, ranging up to 8 ft. in thickness, on the higher parts of the hill between 450 and 460 ft. O.D. At Ashley Hill (475 ft.) it forms one large capping of about the same thickness.

In my former paper,‡ while describing the Ashley Hill deposit, I noted the occurrence of certain small pebbles of reddish quartzite, but, on account of their doubtful character and rarity, I was not prepared to accept them as the true red quartzites of the Glacial Gravel. However, on the evidence of these pebbles, and some others of a black—possibly Carboniferous—chert, Mr. Monckton in a recent paper § stated that he was inclined to suspect that the Westleton Gravel on Bowsey and Ashley had been re-arranged, and had received a mixture of material from the Glacial Gravel. During the past year renewed search has brought to light other specimens of quartzite of a more decided character, both on Ashley and Bowsey. Portions of some of these specimens were submitted to Mr. Monckton who, without hesitation, pronounced them to be identical with the red quartzites of the Glacial Gravel. Though the probability of some intermixing of the two gravels having taken place here is thus greatly increased it must not be forgotten that, as I have already shown, both red quartzites and dark chert are present in the Oxfordshire deposits of Westleton Gravel lying more than 100 ft. above the highest occurrences of Glacial Gravel. The consideration of this point I defer to the end of the paper.

Streatley (Common Wood).—On the high ground which rises very steeply behind the village of Streatley, the Chalk is overlain

* The author, *op. cit.*, vol. xii, p. 379. See also J. H. Blake, *Reading Literary and Scientific Society's Report and Proceedings*, 1891, p. 38 (Report of Excursions).

† *Op. cit.*, p. 141.

‡ "Notes on the Westleton Beds near Henley-on-Thames." *Proc. Geol. Assoc.*, vol. xii, p. 380.

§ "On the Occurrence of Boulders and Pebbles from the Glacial in Drift Gravels South of the Thames." *Quart. Journ. Geol. Soc.*, vol. xlix (1893), p. 314.

by a patch of sand and loam forming an outlier of the Reading Beds. The thin layer of gravel spreading over this outlier, up to a height of 550 ft. O.D. is referred to the Westleton Shingle by Prof. Prestwich,* who does not, however, describe it. As its character is somewhat unusual, it will be as well to give a short account of it here. Its composition is as follows:

1. Angular and sub-angular flints;
2. Pebbles of white quartz, mostly small, ranging up to 2 inches in diameter;
3. Pebbles of light coloured quartzite, up to 3 inches in diameter;
4. Sub-angular pieces and pebbles of light brown sandstone;
5. Flint pebbles (not very abundant);
6. Sub-angular pieces and pebbles of lydian stone, dark slaty rocks, and dark chert;
7. Red quartzites, mostly well worn and pebbly, up to 2 inches in diameter;
8. A few sarsen-stones (one specimen found measuring 9 by 5 by 5 inches);
9. Small pieces of ironstone, and of cherty sandstone.

Of the above materials the little-worn flints and quartz pebbles form the bulk of the deposit, which, at first sight, recalls the Westleton Gravel of Greenmoor Hill. The quartzites and sandstones are, however, fairly abundant, and, saving their inferior size, they are not to be distinguished from those occurring in the Glacial Gravel. For Westleton Gravel the flint pebbles are remarkably scarce, and the proportion of angular flints unusually large; while the number of the characteristic quartz pebbles is normal. I have found it hard to decide in what category this deposit should be placed. While its elevated position (corresponding to that of the Stoke Row deposit in Oxon) is in favour of our regarding it as Westleton, its composition connects it closely with the Glacial Gravel. Perhaps the safest course is to regard it as a mixture of the latter with materials derived from the former.

Before passing on to the consideration of the Glacial Gravel it is necessary to mention that Prof. Prestwich † speaks of the occurrence of Westleton Shingle at Upper Basildon. I have not, however, succeeded in finding anything that could reasonably be referred to this group at that place—the Tertiary outlier which, according to Prof. Prestwich, should be capped by Westleton Shingle being actually covered by Glacial Gravel of an unequivocal kind.

Between Streatley and Maidenhead the Glacial Gravel is confined to a strip of country, rarely more than three miles in width, bordering the Thames. A short distance beyond the

* *Op. cit.*, p. 149, diagram.
† *Op. cit.*, p. 142.

southern margin of this narrow area the ground is occupied by the lower terraces and minor plateaux of the Southern Drift—a gravel which, I need hardly point out, is of a type quite distinct from the Glacial Gravel, consisting, as it does, of sub-angular and pebbly flints, a variable proportion of Greensand chert and other rocks of southern origin, with a few quartz pebbles.

In that portion of the district lying to the east of Reading the Glacial Gravel is but feebly developed, and the widespread sheets of Oxfordshire are represented by a few local patches. The best examples of this drift occur about Bisham and Cookham Dean. The gravel (which is coloured as Glacial on the Survey Drift Map 7) there rests both upon the Chalk and the small outlying masses of Lower Tertiary strata, at elevations of 250 to 351 ft. O.D., and is best seen along the summit of the Quarry Wood ridge, 300 to 351 ft. The variety of rocks there represented is very large, and though Mr. Monckton, who has described the deposit,* noted the occurrence of a block of decomposed igneous rock (porphyrite) more than 12 inches in length, the materials are not on the whole of exceptional size.

At Pinkney's Green, about 240 ft. O.D., rather more than a mile to the south of the above, there is a thin spread of fine flint and quartzite gravel, possibly derived from the older deposits in the neighbourhood.

Between Bisham and Wargrave traces of what may be called either Glacial or high terrace Thames Gravel, occur here and there along the crest of the river escarpment. A section of the most marked of these is to be seen in the road-cutting on White Hill, Remenham, at a height of 300 ft. O.D. This patch seems to be connected with the fine river terrace (200 ft. O.D.) above the village of Remenham, on the north. I have noted the presence of chert here. South of Wargrave the ground is low-lying and covered by gravels which, at Ruscombe, have yielded large numbers of fine palæoliths † to Mr. Treacher's careful search, and which clearly belong to the Thames and Loddon Valleys deposits.

Southward of Sonning, and between the valleys of the Thames and Loddon, there is a marked plateau about 200 ft. O.D., capped by a gravel composed of materials derived alike from the Glacial Gravel and the Southern Drift, and therefore considered by Mr. Monckton to be a mixture of Thames and Loddon deposits.‡ A similar gravel is recorded by the same author at Southern Hill, Reading (210 ft. O.D.). Palæoliths have been found in both.§ To the south the northern materials (red quartzites, etc.) rapidly become scarce, and are quite absent in the gravels about Earley (210 ft. O.D.).

* *Op. cit.*, pp. 312 and 314.
† Shrubsole, *op. cit.*, p. 591.
‡ *Op. cit*, p. 312.
§ Shrubsole, *op. cit.*, p. 590.

West of Reading the Glacial Gravel, though still limited to a comparatively narrow belt of country, forms deposits of more importance, and comparable to those on the opposite side of the Thames. The largest of these gives rise to the Tilehurst Plateau (300 to 343 ft. O.D.) The gravel is well shown in section at the Norcot pits, but as it has already been described by others* I need only remark that special interest attaches to it by reason of the unusually large variety of rocks it includes.

Between the Tilehurst plateau and the Thames, Mr. Monckton notes the existence of a patch of gravel at 275 ft. O.D., which, though very like the Glacial Gravel in composition may, in his opinion, be really a high-level River Gravel derived from the latter.

To the north-west, and beyond the valley of the little river Pang, the Chalk country rises steadily, and on it gravel deposits occur, first in the form of small, ill-defined patches (as at New Town, about 340 ft. O.D.) amidst the spreads of clay-with-flints, and then in masses of more importance. Some of the former, no doubt, must be referred to the valley deposits of the Thames, but here, as elsewhere, it is not possible to draw other than an arbitrary line between Glacial and River Gravel. On and about the outlier of Reading Beds at Upper Basildon (400 to 466 ft. O.D.) the gravel becomes sufficiently developed to impart the characteristic plateau-like features to the country. Its constituents, as shown in the roadside sections, are, on the whole, of rather small size and well-rounded. Pebbles of quartz are abundant, but the typical red and grey quartzites, grits, etc., form the bulk of the deposit. A good deal of ochreous sand and loam is also present. If Westleton Shingle ever existed here it must have been either buried beneath or, more probably, incorporated with the succeeding Glacial Gravel.

Two miles to the north-west, and separated from the Upper Basildon plateau by small branching valleys, there exists between Southridge Farm and Bennett's Wood, a less marked spread of gravel consisting chiefly of angular flints with occasional quartzites, etc., from 450 to 500 ft. O.D.

Near Streatley the slope into the Thames Valley is too steep to have retained any but the thinnest of superficial deposits, in which the Glacial Gravel is doubtfully represented by occasional pebbles.

RELATIONS OF THE GRAVELS.

Having reached the end of the descriptive portion of this paper, I shall now attempt to show what may be deduced from the facts there recorded. The difficulties inseparable from gravel

* Shrubsole, *op. cit.*, p. 583. Monckton, *op. cit.*, p. 309; J. H. Blake, *Proc. Geol. Assoc.*, vol. x (1888) p. 495; and *Reading Lit. and Scien. Soc. Report and Proceedings*, 1890, p. 23.

classification are admittedly great, and I fully realise the inadvisability of basing wide generalisations upon the observation of phenomena presented in a comparatively small district. I shall, therefore, only briefly point out what seem to be the more probable inferences to be drawn from a study of the gravels within the area here dealt with.

The first point to be noticed is the peculiar mode of occurrence of the Westleton Gravel. Though represented by patches more or less widely separated, the relation in which it stands to the subjacent rocks remains fairly constant; the better developed of those patches—*i.e.* those which have suffered least from the destructive agencies—both on the north and south, being confined to the Tertiary outliers. This fact is of special significance when we remember that the rocks of the district possess a marked south-easterly dip, for it points to the deposition of the Westleton Gravel having taken place at some period anterior to that of the main movements which resulted in the formation of the high ground of the Chiltern Hills.

That this high-level pebbly gravel is a deposit of considerable antiquity might, therefore, have been justly inferred from its distribution in this district alone. Thanks to the wide researches of Prof. Prestwich, however, it is no longer possible to doubt that in the Westleton Gravel we have—if not the remnants of a Pliocene bed—at least one of the oldest of the Pleistocene "drifts" of the London Basin.

According to Prof. Prestwich,* the gravel was spread out on a comparatively level sea-floor, or broad coast-line, at a time when the Tertiary strata extended in an unbroken sheet over the Chalk that now constitutes the northern slope of the London Basin: its existence as separate patches at varying heights at the present day being the result of combined detrition and north-westerly elevation. There is nothing in its distribution in this district in the way of our accepting this view. Indeed, the marine origin advocated for it accords well with its wide distribution, its general constancy of position, and its shingly nature. Though the fact that it rests directly upon the Chalk near Checkendon and at Witheridge Hill may, at first sight, seem hard to reconcile with the spreading out at a uniform level throughout the district which the theory demands, the degraded nature of the deposits at those places renders their derivative origin almost a certainty.

The Westleton Gravel has yielded no trace of organisms in Oxfordshire and Berkshire, nor does its incoherent nature render the existence of such in any degree probable.

How far the Westleton Sea may have extended beyond the district to the north-west, *i.e.* beyond the existing Chalk escarpment, we cannot tell; but it is possible that, in the somewhat large proportion of slightly worn flints characterising the deposits

* *Op. cit.*, *Q.J.G.S.*, vol. xlvi, p. 148.

of Greenmoor Hill and Nettlebed, we may have an indication that a limit existed at no great distance in that direction.

With regard to the composition of the Westleton Gravel, there is something to be said. In spite of its general uniformity of character throughout the area, a certain amount of variation is clearly recognisable. Thus, we find that, while at Nettlebed and Greenmoor Hill there is an all but complete absence of materials other than flint and quartz, at all the other localities, and especially those south of the Thames, it contains a noticeable proportion of rocks in addition to those just named. The simple nature of the gravel at Nettlebed was noticed by Prof. Prestwich,* and ascribed by him to the distance of that occurrence from the main mass—an explanation which, though not wholly satisfactory, at least possesses some degree of probability if we assume, with that author, that the constituents of the Westleton Shingle were derived from some south-eastern source. In the present state of our knowledge it is not, however, possible to speak with any degree of certainty as to the causes that produced the local variations in the composition of the gravel in question.

The presence of the red quartzites, sandstones, and dark Palæozoic chert in the deposits of Stoke Row, Bowsey, and other localities, introduces an element of uncertainty into the classification adopted by Prof. Prestwich: for if these materials—and particularly the red quartzites—are indeed identical with those so abundant in, and characteristic of, the Glacial Gravel, it would seem either that one of the chief constitutional distinctions insisted on by Prof. Prestwich, as existing between the two gravels does not always hold good, or that no true Westleton Gravel (unless it be at Nettlebed) exists in this district.

Personally, I am not inclined to attach much importance to the occurrence of these doubtful rocks. The red quartzites never hold more than a subordinate position among the rarer constituents of the gravel, their size is invariably small, and, in most cases, a careful search is required to reveal their presence at all. Whatever significance these rocks may eventually be found to possess—whether they may indicate that the constituents of the Westleton Gravel were not only derived from the south-east, but also from the north-west, or whether they are to be regarded as the earliest sign of the incoming of the Glacial Gravel—they will not prejudicially affect the claims of the Westleton Gravel, as a whole, to a distinctive title.

If it be granted that the Westleton Gravel was originally spread out on an approximately level floor, I think it will also be admitted that a long time must have elapsed between its deposition and that of any younger drift unquestionably referable to the Glacial Gravel; for the latter rests, for the most part, upon the eroded surface of the Chalk at lower levels than, and at some

* *Q.J.G.S.*, vol. xlvi, p. 140.

distance from, the Tertiary outliers bearing the former—a condition of things pointing to the intervention of very appreciable changes in the physiography of the region.

The relative positions of the two gravels will be more easily realised from an inspection of the accompanying diagram sections (Figs. 1, 2, 3). In these sections the difference in the distribution of the Westleton and Glacial Gravels is very noticeable, the isolated hill patches of the former forming a marked contrast to the wider spreads of the latter. The vertical and horizontal breaks between the two sets of deposits are also apparent.

It will be remarked that the Glacial Gravel attains its greatest height (of about 500 ft. O.D.) at its north-western limit, and shows a general falling away in a south-easterly direction, which may partially be the result of earth-movements that took place after, or during, its deposition. There are, however, frequent and somewhat rapid variations in level, which show that the several masses and plateaux are not simply separated portions of a once continuous sheet. This point has an important bearing on the origin of the gravel, shortly to be discussed.

The materials of which the Glacial Gravel is composed are derived from two distinct sources: the flints in all states, the fragments of sarsen-stone and ironstone, and the smaller quartz pebbles either directly from the Cretaceous and Eocene beds, or from the older drifts of adjacent areas; the red quartzites, grits, sandstones, blocks of vein-quartz, etc., from the Trias of the Midlands. Doubtless the two sets of materials were already mingled when they reached this district, but it is interesting to note the increased size and number of the foreign constituents to the west, in the neighbourhood of Goring.*

The task of deciding under what conditions the older drifts—and particularly those included in the glacial category—have been formed, is one rarely devoid of great difficulties, the only obtainable evidence being, too often, of fragmentary, uncertain, and seemingly contradictory nature. In the present case, although the phenomena exhibited may be capable of more than one interpretation, they seem to me to point very distinctly to the conclusion that, whatever may have been the conditions under which the red quartzites and other foreign rocks were introduced into this area, the spreading out of the product of their mixture with local materials—which is known as the "Glacial Gravel"—was accomplished by fluviatile agency.

I have more than once adverted to the difficulty encountered when endeavouring to draw a line of demarcation between the upper terraces of the Thames deposits, and the lower spreads of

* The converse of this—viz., the easterly decrease in the proportion of red quartzites in the gravels of the Thames area—is noticed by Dr. Buckland in his *Reliquiæ Diluvianæ*, p. 252 (1823), to which the reader is referred for an interesting account of the dispersion of these Triassic pebbles. See also *Trans. Geol. Soc.*, vol. v, part ii (1821), pp. 507-544.

the Glacial Gravel. This difficulty has presented itself, probably, to all who have interested themselves in the drifts of the Thames valley. For example, Mr. Whitaker * remarks that many of the masses of gravel in the district adjoining London on the west are coloured as Glacial on the drift maps only as a matter of probability and admits that "some may possibly be only very high terrace river gravel." Mr. O. A. Shrubsole also, in his paper "On the Valley Gravels about Reading,"† notes that there is a difficulty in making out a clear line of demarcation between the River and the Plateau (*i.e.* Glacial) Gravel; and Mr. Monckton has stated that he thinks it probable that the higher terraces of the River Gravel were contemporaneous with the Glacial Gravel.‡

The inability to separate the two gravels is felt most where the slope into the Thames valley is gradual; but even where the sides of the valley are too steep to have allowed of the accumulation of gravel at intermediate heights, and the separation would seem to be more easily effected, there is nothing in the composition or structure of the deposits to distinguish them, and the occurrence of flint implements in the higher gravel (as at Caversham, Emmer Green, and Sonning Hill) shows the distinction to be merely superficial. Now if the lower spreads of the Glacial Gravel are so closely related to the River Gravels as not to be logically separated from them, their connection with the higher members of their own division is certainly no less obvious, and, following up this train of reasoning, the conclusion arrived at is, that the Glacial Gravel is nothing more than an old deposit of the Thames. Though to some this may seem an extreme view, I do not think there is anything inherently improbable in it. The fact that the Glacial Gravel is limited to a belt of variable width on either side of the Thames is, in itself, almost a proof that some intimate relation exists between it and that river §; while the close similarity of its composition and that of deposits indisputably belonging to the latter, though, of course, not necessarily implying identity of origin, certainly favours that conclusion. Even if we disregard, for the moment, its relations to the Thames, we cannot but admit that its mode of occurrence as ridges, plateaux, and gently-inclined terraces at varying heights; its generally angular nature; its bedded structure, as revealed in sections; and its constant association and alternation with sand and loam, suggest nothing so much as fluviatile action.

The area over which this gravel extends is certainly great, but this fact does not militate against its suggested origin; for it is not necessary that a river capable of forming such a wide-spread

* *Geology of London* (1889), pp. 300, 301.

† *Quart. Journ. Geol. Soc.*, vol. xlvi, p. 582.

‡ *Ibid*, vol. xlix (1893), p. 324.

§ In *Reliquiæ Diluvianæ*, p. 279, Dr Buckland gives a drift map of the country round Oxford, which exhibits, in the clearest manner, the close relation existing between the present lines of drainage and the distribution of the gravels containing Triassic débris.

deposit should have occupied more than a small proportion of that area at any given time. Indeed, if this Glacial Gravel does owe its existence to fluviatile agency, the varying heights of its component sheets can only be explained by a recurrent shifting of the course of the stream during the earlier stages of valley excavation.

To be brief, if the highest deposits of the Glacial Gravel, which are also, as a rule, the most remote from the present main line of drainage, are to be considered the oldest, it would seem that the early representative of the Thames (to which, on the present theory, they are attributed), on entering the district from the west, and on the site of the existing Goring Gorge, at first flowed in a more northerly channel, whose general trend—probably determined by the then existing Lower Tertiary escarpment—is indicated by the terraces above Whitchurch, near Exlade Street, Highmore, and Fawley. There is reason for thinking that at that epoch the Secondary and Tertiary rocks were still undergoing the movements of which their present south-easterly dip is an outcome, and, possibly, it was as a result of the increasing elevation of the ground on the north-west that the river gradually modified its course, and, working laterally down the dip slope, left behind it the wide gravel-spreads of south-eastern Oxfordshire to mark its successive positions. The deposits of Upper Basildon, Tilehurst, Bisham, etc., in Berkshire show, it is true, that at times part of its course lay slightly to the south of the present valley of the Thames, but the occurrence of the more extensive sheets on the north proves that, whatever its cause, the balance of the lateral shifting was in a southerly direction. In its later stages, and since the formation of the highest implement-bearing terraces of the district, the Thames would seem to have devoted its erosive energies to deepening rather than to widening its valley.

On this view the occurrence of that characteristically southern material, Greensand chert, on the northern side of the river, is less remarkable: we should, indeed, expect to find among the older Thames Gravel some such evidence of the existence of southern affluents representing the Loddon and the Kennet.

The tributary streams, both from the south and the north, by furnishing local material, have, no doubt, helped to swell the older gravels, but the broad valleys and deep coombes they have excavated in later times have done much to break the original continuity of contemporaneously formed deposits, and, by affording in themselves channels by which the débris could be readily removed, have further aided the subaërial agencies in the destruction of the portions remaining on the intervening plateau-ridges.

It will be evident (if the view as to its origin here taken be accepted) that we cannot assign any one age to the "Glacial" Gravel of this district—its deposition having commenced at some

remote date (though certainly posterior to the passing away of the "Westleton" conditions), and continued down to, relatively, recent times. Although its formation may thus have been, in part, contemporaneous with what is known as the Glacial Period, there is little reason to think that *ice* ever played an important part in its local distribution. Nothing resembling boulder clay occurs in the district; and in the gravel itself there is a general absence of those folded and contorted appearances which are exhibited by similar deposits in the eastern counties, and commonly attributed to the action of ice, in one form or another.*

The large blocks of quartz and quartzite characterising the gravel near Goring Heath and Whitchurch, which must have required a rapid and powerful stream for their transportation, might, perhaps, be taken as an indication of climatic conditions of some severity, but cannot be regarded as proof that glacial conditions (in the ordinary sense of the term) obtained within the limits of the district.

So far as I have seen, there is nothing to justify the somewhat indifferently held opinion that the high level gravel with red quartzites of the western quarter of the London Basin, is a marine deposit. Indeed, I think it will be apparent that the facts favouring a fluviatile origin are alone sufficient to disprove such an assumption.

In conclusion, I should like to say that I have only attempted to give a general account of the older gravels of a portion of the London Basin lying, for the most part, beyond the limits of the area whose drifts have been described in the publications of the Geological Survey.

I trust that—in spite of its many shortcomings—this paper may not be altogether without interest to those who find the physiographical problems presented by the distribution of the drifts of the Thames area an attractive subject for study.

* It should be mentioned, however, that Mr. Shrubsole has called attention to signs of irregular deposition and disturbance in the valley gravels about Reading at and below the comparatively low elevation of 197 feet O.D. *Op. supra cit.*, p 592.

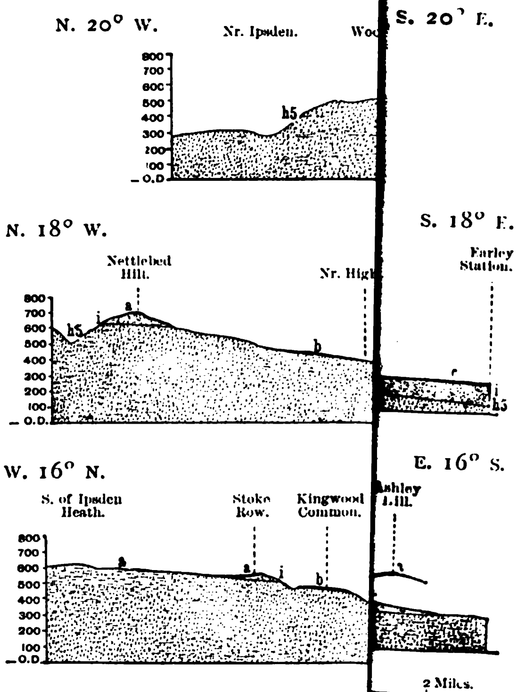
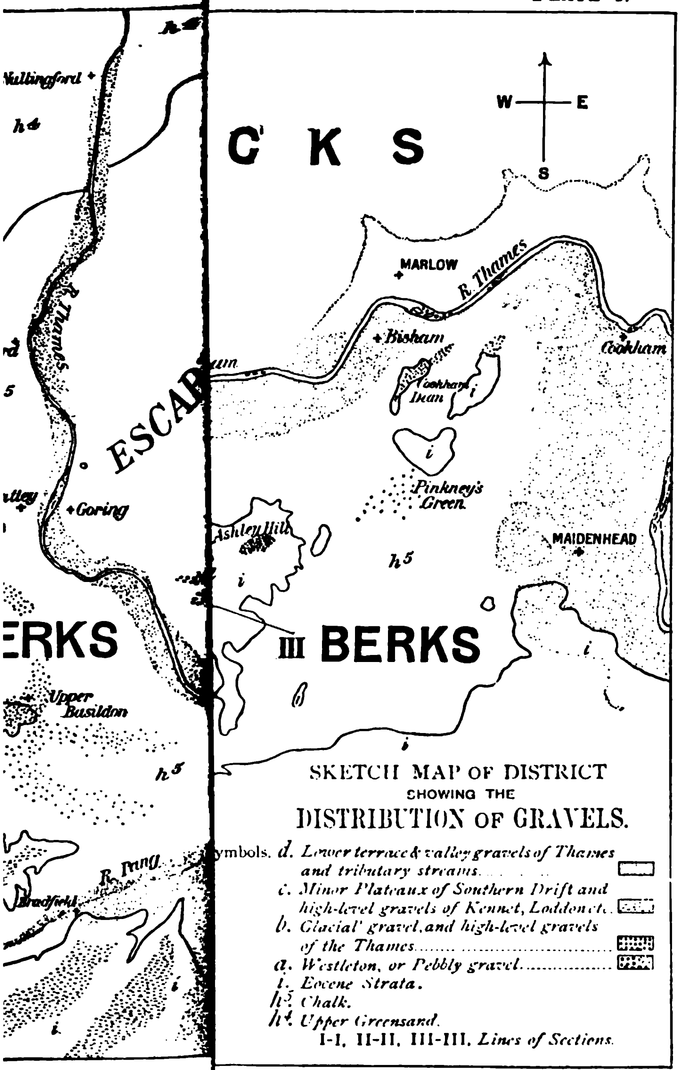


Diagram Sections:
I. Greenmoor Hill to Tilehurst ...don, etc.
II. Nettlebed Hill to Earley.
III. Stoke Row to Bowsey Hill.

PLATE I.



H. J. Osborne White.

ƆTE ON MEGALOSAURIAN TEETH DISCOVERED BY MR. J. ALSTONE IN THE PORTLANDIAN OF AYLESBURY.

BY A. SMITH WOODWARD, F.Z.S.

[*Read 7th December, 1894.*]

YEAR ago, Mr. John Alstone discovered in the Beagle Pit at Hartwell, near Aylesbury, two teeth of a Sauropodous iosaur, which were described by Mr. Lydekker, and provision- ascribed by him to *Pelorosaurus humerocristatus.** Since t time Mr. Alstone has continued his observations in this well- 'wn locality, and quite lately he has succeeded in obtaining only another tooth of the same animal (probably the same), but also three other teeth of an equally interesting character. :se belong to a carnivorous Dinosaur, and are of the form ımonly described under the name of *Megalosaurus.* They indeed, identical with the typical teeth of this genus found in Stonesfield Slate, and might be definitely assigned to it, were ot for the fact that such teeth are now known to characterise hole group of animals which cannot be distinguished by the tition alone.

Two of the new specimens (Nos. I and II) differ merely in both being high-crowned and stout, feebly facetted, and ıpressed only on the posterior margin, which is slightly con- and exhibits conspicuous serrations as far as the base. In ı, the apex is worn into two distinct surfaces—a vertically ıgated streak on the flatter face, a shorter and broader area he more convex face ; in this manner all traces of serrations he anterior border, if ever present, have been obliterated. The d specimen (No. III) is shorter, broader, much more laterally ıpressed and arcuated ; it is scarcely, if at all, worn at the , and the serrations not only extend the whole length of the cave posterior border, but also more feebly along the upper d of the much-arched anterior border. This specimen is also resting as exhibiting the channels of a small burrowing anism, which show that the tooth must have lain exposed for e time at the bottom of the water before being buried. asurements in decimal fractions of a metre are as follows :

	I	II	III
Height of crown .	0·036	0·030	0·031
Max. breadth of crown	0·014	0·012	0·016
Max. thickness ,,	0·010	0·009	0·008

R. Lydekker, "On Two Dinosaurian Teeth from Aylesbury," *Quart. Journ. Geol. Soc.,* lix, pp. 566-568, with figs. (1893).

Whether the three teeth thus described belong to a single jaw, cannot be ascertained, though such is very likely to be the case. They are, indeed, insufficient for specific determination; but their interest lies in the fact that the stratum whence they were obtained is regarded as of Portlandian Age.* Megalosaurian teeth are well known in this country both below the Portlandian and above it (in the Wealden), but none have hitherto occurred in any English deposit of this period. Moreover, the only teeth of the same type as yet discovered in corresponding strata on the Continent differ considerably from Mr. Alstone's new specimens in the relatively great breadth of their crown and the coarseness of their serrations †

* J. F. Blake, "On the Portland Rocks of England," *Quart. Journ. Geol. Soc.*, vol. xxxvi, p. 215 (1880).

† *Megalosaurus insignis*, Deslongchamps, in Lennier's *Etudes Géol. et Paléont. Embouch. Seine*, p. 35 (1870).

ANNUAL GENERAL MEETING.

FEBRUARY 1ST, 1895.

Lieut.-General C. A. McMAHON, F.G.S., President, in the Chair.

Dr. G. J. Hinde and Mr. J. Slade were appointed Scrutineers of the ballot.

The following Report of the Council for the year 1894 was then read :—

THE numerical strength of the Association on the 31st of December, 1894, was as follows :—

Honorary Members	16
Ordinary Members—	
a. Life Members (Compounded)	159
b. Old Country Members (5s. Annual Subscription)	8
c. Other Members (10s. Annual Subscription). .	358
Total	541

During the year 27 new members were elected.

The Council regrets that the Association lost 9 members by death : Mrs. Cohen, J. Frost Creswick, W. Holmes (of Balham), H. B. Mackeson, Charles Gill Martin, A. R. S. Methven, J. Bickerton Morgan, Adam Murray, William Topley. J. Bickerton Morgan, one of the most promising geologists of the younger school, had only been elected a member in 1893 ; Henry Bean Mackeson, an old member of the Association, had contributed to your PROCEEDINGS, assisted in your excursions, and will be long remembered for his work and discoveries in the Hythe Beds ; Adam Murray, one of the oldest and best-known members, was, until recent years, a constant figure at your excursions. We have also to deplore the loss of William Topley, who became a member in 1882. Mr. Topley held the office of President for 1885-1887, and was almost continuously a member of your Council, which he regularly attended, taking the utmost interest in your affairs. You yourselves knew him best as an admirable leader in the excursions, and his death makes a gap in the ranks of the true friends of the Association which it will be very difficult to fill.

Omitting the "Record" and "Paris Basin," the income of the Association for 1894 was £236 4s. 9d., and the expenditure

GEOLOGISTS' ASSOCIATION.

Dr. Income and Expenditure for the Year ending Dec. 31st, 1894. **Cr.**

	£	s.	d.		£	s.	d.
To Balance from 1893 ...	5	11	2	By Printing "Proceedings" ...	88	6	4
" Life Compositions ...	23	5	0	" " Monthly Circulars ...	19	0	6
" Admission Fees ...	13	10	0	" Illustrating "Proceedings" and Circulars ...	14	19	4
" Annual Subscriptions ...	169	5	0	" Miscellaneous Printing ...	15	3	9
" Dividends on Nottingham Corporation Stock ...	23	2	10	" Postages ...	36	14	0
" Sale of Publications ...	7	1	11	" Addressing ...	8	8	0
" Sale of "Record" ...	6	0	0	" Library ...	8	18	3
" Sale of "Paris Basin" ...	0	16	8	" Binding Stock of "Record" ...	2	6	11
				" Attendance, Gas, etc., at Evening Meetings ...	18	12	0
				" Excursions ...	13	1	4
				" Insurance ...	1	10	0
				" Stationery ...	4	10	3
				" Miscellaneous Expenses ...	0	18	11
				" Cash in hand, Dec. 31st, 1894 ...	16	3	0
	£248	12	7		£248	12	7

We have compared the above account with the vouchers and find it to be correct.
We have also verified the investment of £797 17s. 3d. Nottingham Corporation Stock.

11th January, 1895.

JAS. D. HARDY,
JOHN HOPKINSON. } *Auditors.*

£230 2s. 8d. These figures show a certain falling off in the receipts as compared with the last few years, which is due to a combination of causes. In the first place the raising of the composition fee has, as was anticipated, reduced the receipts from that source, there having been four compounders last year (only one of whom paid the increased fee), as compared with eight, the average of the last few years. Then the number of new members elected was smaller than usual. This has its effect on the receipts from annual subscriptions as well as on the admission fees. Further, the income derived from the sale of publications has diminished, and there was none at all from advertisements. Nevertheless, the expenditure has been kept well within the income, and that without in any way cutting down the sums usually allotted to the various items that go to make up the total, while a balance of £16 3s. has been carried on to the current year. Although, therefore, your Council has not been able to ask the trustees to invest any money during the past year, it will be seen that the usefulness of the Association has been in no way curtailed, and your Council considers that the members have every reason to be satisfied with its financial condition.

During the year the usual five numbers of PROCEEDINGS have been published; these, with the title pages, contents, and index since issued, complete Volume XIII. These five numbers comprise 204 pages, with five plates and a folding diagram; there are in addition thirty-eight illustrations in the text. You are indebted to Mr. A. Smith Woodward for Plates V and VI, and to Mr. W. W. Watts for Plates VIII and IX.

A large number of Memoirs of the Geological Survey, including the "Lower Oolitic Rocks of England," by H. B. Woodward, has been presented to the library by the Director-General of the Geological Survey. To the liberality of the Government of the United States of America, the Association is indebted for numerous Monographs and Bulletins of the United States Geological Survey.

Seventeen volumes of completed Memoirs of the Palæontographical Society have been bound, and thus rendered available for circulation. *The Geological Magazine*, *The Quarterly Journal of the Geological Society*, *The Proceedings of the Societies of Liverpool and Manchester*, and *The Bulletins of the Société Géologique de France*, and of the Geological Society of America have all been bound up to date, and can now be issued to members. Altogether fifty-five volumes have been bound during the year. The Council would draw attention to the fact that all the books in the library are now accessible to the members.

Your thanks are due to Mr. Henry Fleck for assisting the Librarian in preparing for the issue of a revised Catalogue.

The following is a list of the Papers read at the evening meetings:—

"On the Genesis of the Chalk," by W. FRASER HUME, D.Sc., F.G.S.

"Geology in the Field and in the Study," by HORACE B. WOODWARD, F.G.S.

"The Hythe Beds of the Lower Greensand in the Liphook and Hindhead Districts," by BINSTEAD FOWLER.

"Tertiary Man," by J. B. M. FINDLAY.

"Note on a large Mass of Chalk at Catworth, in Huntingdonshire," by A. C. G. CAMERON, M.A., F.G.S., with an appendix "On some Boulders collected by Mr. Cameron," by W. W. WATTS, M.A., F.G.S.

"On the Distribution and Relations of the Westleton and Glacial Gravels in parts of Oxfordshire and Berkshire," by H. J. OSBORNE-WHITE, F.G.S.

"The Geology of South Shropshire," by Professor CHARLES LAPWORTH, LL.D., F.R.S., and W. W. WATTS, M.A., F.G.S.

"Notes of a Geological Excursion in Switzerland," by Professor MCKENNY HUGHES, F.R.S., H. W. MONCKTON, F.G.S., and Dr. FRASER HUME.

Lectures were delivered by Dr. G. J. Hinde, F.G.S., on "Fossil Sponges: their characters, modes of occurrence, and conditions of preservation," on April 6th; and by Professor Lapworth, LL.D., F.R.S., on "Geology and the Relief of the Globe." Your thanks are due to these lecturers.

Instead of the usual conversazione, held in November, your Council decided to hold a lantern exhibition of slides of geological interest. From the excellence of the exhibition, and the general approval expressed by those present, the Council has reason to believe that this innovation was appreciated by the members. Your thanks are due to those who contributed to the success of the exhibit, especially to Messrs. Geo. F. Harris, Edouard Lardeur, Wm. Thomas, C. J. Burrow, and Henry Preston, the latter member having journeyed specially from Grantham to assist in the success of the evening.

The following Museums, etc., were visited during 1894:—

The Collection of Flint Implements and Restored Flints from Crayford formed by Mr. F. C. J. Spurrell, on March 10th, when an address on "The Process of Manufacture of Flint Implements by Pre-historic Man," was delivered by Mr Spurrell.

The British Museum (Natural History), on March 17th, when the Keeper of Geology, Dr. Henry Woodward, F.R.S., P.G.S., gave a demonstration on the "Fossil Reptilia."

The Woodwardian Museum, Cambridge, on May 13th, when Prof. T. McKenny Hughes, F.R.S., F.G.S., Woodwardian Professor of Geology in the University, gave a short address on the origin and contents of the Museum.

The Collections of Flint Implements and other Pre-historic Remains, chiefly from the neighbourhood of Caddington and Dunstable, formed by Mr. Worthington G. Smith, F.L.S., on May 26th, when the collections were explained by Mr. Smith.

The Shrewsbury Museum, on August 3rd, when the party was received by Mr. Wm. Lyon Browne, Mayor of Shrewsbury, and the contents of the Museum were explained by Mr. Phillips.

The following is a list of the excursions made during the past

year, detailed reports of which will be found in numbers 8 and 10 of vol. xiii of the PROCEEDINGS:

DATE.	PLACE.	DIRECTORS.
March 10th.	East Wickham (Kent).	F. C. J. Spurrell, F.G.S.
March 23rd to 27th (Easter).	Bournemouth, Barton, etc.	J. Starkie Gardner.
April 14th.	Harefield.	Upfield Green, F.G.S.
April 28th (whole day).	Wellingborough.	Beeby Thompson, F.G.S., and W. D. Crick, F.G.S.
May 5th.	Oxted and Titsey.	G. Leveson Gower, F.S.A., and W. Topley, F.R.S.
May 12th to 15th (Whitsuntide).	Cambridge and Ely.	Prof. T. McKenny Hughes, F.R.S., and J. E. Marr, F.R.S.
May 26th (whole day).	Caddington and Dunstable.	J. Hopkinson, F.G.S., and Worthington G. Smith, F.L.S.
June 2nd.	North Finchley and Whetstone.	Dr. H. Hicks, F.R.S.
June 16th.	Gravesend and Northfleet.	Prof. T. Rupert Jones, F.R.S., and F. C. J. Spurrell, F.G.S.
June 23rd.	Redhill and Nutfield.	C. J. A. Meyer, F.G.S., and H. W. Monckton, F.G.S.
June 30th (whole day).	Herne Bay.	W. Whitaker, F.R.S.
July 21st.	Guildford.	J. W. Gregory, D.Sc., F.G.S.
July 30th to August 4th (Long Excursion).	Shropshire.	Prof. C. Lapworth, LL.D., F.R.S., and W. W. Watts, M.A., F.G.S.
November 10th.	Elstree.	Rev. Prof. J. F. Blake, M.A., F.G.S.

Increased interest has been manifested during the past year in the excursions of the Association, and the attendance of members and their friends has been exceptionally large. Upon two occasions the proceedings were somewhat hampered by a large influx of members, without previous notice having been given; although fully aware of the difficulties of this question, your Council desires to impress upon all the desirability of giving notice of intended participation in excursions, when requested to do so. However, to meet the growing wants of the Association, it is hoped during the ensuing season to slightly increase the number of short excursions near London, by which means the typical localities will be visited more frequently in a course of years.

Your thanks are due to the directors of all the excursions; also to the following ladies and gentlemen for assistance and hospitality:—

Mr. F. C. J. Spurrell, F.G.S., on March 10th; Dr. H. Woodward, F.R.S., P.G.S., on March 17th; Mr. F. Pilkington, F.C.S.,

on April 28th; Mr. G. Leveson Gower, F.S.A., and Mrs. Leveson Gower, on May 5th; Mr. Jas. Parker, F.G.S., and Mr. W. Colchester, F.G.S., on May 14th; Mr. Worthington G. Smith, F.L.S., on May 26th; Rev. H. Brass, F.G.S., on June 23rd; Mr. W. Lyon Browne, Mayor of Shrewsbury, Rev. Prof. J. F. Blake, M.A., F.G.S., Dr. C. Callaway, M.A., F.G.S., Mr. R. S. Herries, F.G.S., Rev. J. D. La Touche, and Mr. Phillips, at the Long Excursion.

Your Council has observed with increasing satisfaction the general attendance at the meetings, and the decided increase in the number of exhibits, and in this direction they would especially thank Prof. McKenny Hughes, Mr. H. W. Monckton, Dr. Fraser Hume, Mr. G. E. Dibley, Mr. Llewellyn Treacher, Mr. Salter, Mr. Alford, Mr. Osborne White, and Mr. Upfield Green.

Your thanks are due to the Council of University College for the facilities they continue to offer to the Association, and to Mr. Horsburgh, the Secretary of the College, for the courteous manner in which he furthers the wishes of your Council.

The changes in our House List this year are very few. Our old friend, Mr. Hudleston, retires from the Vice-Presidency, and Prof. J. F. Blake retires at his own request, as he has undertaken important work in India for the Gaekwar of Baroda. Mr. Bradford, Mr. Rudler, and Dr. Gregory retire from your Council. Your thanks are due to all these gentlemen for the care they have shown over your affairs.

The names of those suggested by your Council to fill the vacant offices will be found on the balloting papers.

On the motion of Mr. J. Slade, seconded by Mr. Busby, the Report was adopted as the Annual Report of the Association.

The scrutineers reported that the following were duly elected as Officers and Council for the ensuing year:—

PRESIDENT:

Lieut.-Gen. C. A. McMahon, F.G.S.

VICE-PRESIDENTS:

Miss C. A. Raisin, B.Sc.
H. B. Woodward, F.G.S.
Dr. G. J. Hinde, F.G.S.
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On the motion of Mr. Salter, seconded by Mr. Fleck, the thanks of the Association were unanimously voted to the officers and members of Council retiring from office, to the auditors, and to the scrutineers.

The President then delivered his address, entitled "The Geological History of the Himalayas."

On the motion of Dr. Hinde, seconded by Mr. Potter, it was unanimously resolved that the President's address be printed *in extenso.*

This terminated the Annual Meeting.

ORDINARY MEETING.

FRIDAY, FEBRUARY 1ST, 1895.

General McMAHON, F.G.S., President, in the chair.

The donations to the library, since the last meeting, were read, and thanks were accorded to the several donors.

There being no paper, the meeting then terminated.

ORDINARY MEETING.

FRIDAY, MARCH 1ST, 1895.

General McMAHON, President, in the chair.

Geo. Thurland Prior, Richard Holland, and Miss A. Dakin were elected members of the Association.

The donations to the library, since the last meeting, were read, and thanks were accorded to the several donors.

Mr. LAZARUS FLETCHER, F.R.S., gave a lecture on "Meteorites," which was illustrated by the oxy-hydrogen lantern.

Mr. J. R. GREGORY exhibited a case of Meteorites in illustration of Mr. Fletcher's paper.

ORDINARY MEETING.

FRIDAY, APRIL 5TH, 1895.

General McMAHON, President, in the chair.

D. D. Warhurst-Powel and H. Nalder were elected members of the Association.

The donations to the library, since the last meeting, were read, and thanks were accorded to the several donors.

Mr. WINTOUR F. GWINNELL, F.G.S., read a paper on "The Rocks and Scenery of Western Norway," which was illustrated by lantern photographs, taken by the author and others, and by rock specimens.

NOTES OF A GEOLOGICAL EXCURSION IN SWITZERLAND.

By PROF. T. McKENNY HUGHES, M.A., F.R.S., F.S.A., F.G.S., HORACE W. MONCKTON, F.L.S., F.G.S., AND W. FRASER HUME, D.Sc., A.R.S.M., F.G.S.

[*Read 7th December, 1894.*]

WE propose in the following pages to give a short sketch of some geological phenomena observed by us on excursions made during and after the meeting of the International Geological Congress, at Zurich, in 1894. On these excursions we were under the guidance of able Swiss geologists, and our thanks are more especially due to Dr. A. Heim, Dr. A. Baltzer, Prof. E. Renevier, Prof. H. Golliez, and M. Lugeon. An extremely useful little guide-book to Swiss Geology was provided for us, and is referred to in the following pages as the Livret-Guide: a copy will be found in the library of the Geological Society.

PART I.—BY PROF. McKENNY HUGHES.

Earth Movements.—The first point to which we wish to direct attention is the extent of recent earth movements which have directly affected the existing physical geography of, at any rate, some parts of central Switzerland. On the margin of the Lake of Zurich, Dr. Heim pointed to certain beds of glacial and alluvial origin, which he contended prove either a reversal of the direction of transport of material or a subsequent change in the inclination of the ground on which that material was deposited. The top of Uetliberg consists of a conglomerate, locally called Deckenschotter, which rests upon a stiff lead-coloured boulder clay full of scratched stones. It was so compact that it commonly stood in a cliff or steep slope, and in wet weather the surface became reduced to a sticky unctuous clay, with which some of our party entered into close personal relations, realising that the mass was rather to be regarded as a clay with scattered boulders than a gravel with the interstitial part filled with clay, a process which has frequently taken place subsequently to the deposition of the gravel, and has sometimes caused the deposit to be wrongly described. About this mass, however, there could be no mistake. It was a genuine Boulder Clay in its original state. The rock is made up of the coarser fragments winnowed out of the boulder clay, and compacted by a calcareous cement derived from the fragments of limestone of which the conglomerate is so largely composed. This conglomerate belongs to an age of valley denudation after or coinciding with the recession of the ice, when heavy rain and melting snow caused frequent floods and the rapid destruction of older superficial deposits. The transport of material must have

been down valley and no deposits could have been laid down in the upper reaches of the valley at a lower level than the synchronous deposits farther down the same valley. Now, along the margin of the Lake of Zurich there are gravel beds, some of which so far as they can be traced continuously are seen to be inclined down valley. There are also ledges cut by valley denudation in the Miocene which form conspicuous features along the lake, and it was pointed out that some of these terraces rise to higher levels in the direction of the present fall of the valley, and in pursuance of this line of argument it was sought to identify the conglomerate on the top of Uetliberg with a gravel terrace seen at a much lower level on the south side of the lake near Horgen, that is to say, higher up the valley than Uetliberg. This identification was questioned by some geologists present, but even if this example was not sufficiently clear to carry conviction, we may regard it as an illustration of the kind of evidence which has led such competent observers as Professors Heim and Penck to the conclusion that this whole region in front of the higher mountain ranges of Switzerland has suffered unequal and very appreciable movements of elevation and depression since the last great extension of the Alpine ice.

The bearing of this upon the theory of the glacial origin of rock basins is perhaps the most interesting question involved. If it can be shown that the upper part of the Lake of Zurich has been depressed along an axis of movement in comparatively recent times, and that in this case a rock barrier has been formed by the relative uplift of the region about its outfall, and if such movements are common along the foot lands of mountain regions, it destroys at once the principal argument for the glacial origin of rock basins which is founded on the observation that they generally occur below or along the flanks of glaciated mountains.

An examination of the map of Switzerland, with the knowledge that earth movements along N.E. and S.W. axes have been repeated down to, geologically speaking, recent times, must suggest that the lakes are connected directly with those movements, as they occur so constantly along a N.E. and S.W. belt of country from the Lake of Constance to the Lake of Thun.

Denudation.—We pass on now to consider the denudation which has accompanied the earth movements of which we have spoken, and as we look round from Uetliberg, on the top of which we find the very recent gravel forming the Deckenschotter, we can have no doubt as to the enormous extent of this denudation. We wonder where the material has all gone to! What area of contemporary depression got filled up while the upward movement that facilitated denudation went on here? If we feel a doubt as to whether these vast changes have been brought about in the recent times to which all the evidence seems to point, we

remember the proofs offered of earth movements, and look upon the amount of waste as corroborative evidence, seeing that such movements must directly influence denudation. However averse we may be to all attempts at giving a numerical estimate of these great periods of time where so many various conditions are known to have prevailed affecting all the elements on which our estimate could be founded, still we must carry away from Uetliberg a wholesome impression of the vastness of the operations with which we have to deal when we think that, on that isolated relic of a ridge at that great height above the lake, we are standing upon a patch of valley alluvium of later date than the last great age of Alpine ice.

But unless we suppose that the age of earth movements had ceased, those on which we were speculating at Zurich were only proportionate to, or perhaps we might say small compared with those which had obviously occurred in the preceding periods over the same area. The mass of water-sorted material of which the Rigi is built up implies a direct submergence in Tertiary times to a depth at least as great as the total thickness of the continuously deposited strata, *i.e.*, 8,000 or 10,000 feet, and they are now again elevated to a like height above the sea. The great diversity of the constituents proves that considerable earth movements and vast denudation had previously taken place to expose the edges of such a variety of rocks to the denuding agents.

Travelling afterwards into the heart of the great mountains, though the evidence of later movement was not seen except in the distribution of the lakes, the proofs of vast denudation were forced on us at every turn. Above Meyringen, for instance, after passing a long way through the gorge of the Aar, we climbed to the top of the great barrier that dams the lower end of the Innertkirchen basin. This barrier we found cut by a valley which has left but a small mark in the top of the steep southern front of the declivity up which the road climbs, but deepens in its northward course. The deep gorge along the western margin has tapped all the water that used to flow through the higher channel. Round the end of this valley, at the level determined by the higher outflow, run terraces marking the former level of the water. Here we have the ancient beach remaining unobliterated through the long ages that elapsed while the gorge was being cut back to tap the waters of the Innertkirchen lake. Shall we wonder that the terraces were so enduring, or that the time required for cutting back the gorge has been so short?

Rock Folding.—The next matter which arrested our attention was the enormous extent of the folds into which the rocks had been forced by earth movements of all ages down to comparatively recent times, and the effects of which we saw in every

geographical feature. Heim* has estimated that the sedimentary rocks of the Alps have been crumpled up so that the area occupied by them is only about half the breadth that would be covered if the folds could be straightened out and the beds laid flat. We must not, however, suppose that this means a shifting of the marginal portions of the crumpled area to the extent of the 120,000 metres upon which his calculation is founded, for it is clear that the superficial extension of the folds is at the expense of the thickness of the beds.

We had an opportunity of seeing many of the sections in which the rocks were violently plicated and the sharp anticlinals lay as if they had been thrown over towards the outside of the chain. One limb of the fold was frequently broken and displaced; indeed, we generally felt that too little importance had been attached to the faults which had relieved the intensity of the crumpling, and diminished the actual interval between discordant formations. Along the shores of the Lake of the Four Forest Cantons, as some of us had seen on a previous excursion with Dr. Heim, there were beds sigmoidally folded on themselves, so that the same bed might have been pierced three times in one vertical shaft. These folds were in the Eocene and Cretaceous rocks. The Miocene beds were also folded, but as in them also the intensity of the crumpling increased from north to south, it was not clear how far the more violent contortions of the rocks which were situated farther south may have been due to this fact, and how far it indicated movements in the older rocks previous to the deposition of the Miocene.

Along the east side of the most southerly reach of the lake, where it has the name of Uri, we see the remarkable area described by Heim and Schmidt, where Eocene beds are folded into the Neocomian so as to be seen in section like kernels in a nut, while in places the sharply-puckered rocks run in vertical frills from base to summit. As the great lines of disturbance run parallel to the trend of the principal mountain ranges and valleys, we do not notice the intensity of the plications so much when we are travelling in a N.E. and S.W. direction as when our path takes us across the folds.

The dragging out of the beds in one direction, and folding and puckering in the transverse section, is the commonest structure everywhere among violently-disturbed rocks, whether the result is seen in the great folds of the Lake of Brienz, for instance, or in the mullion structure of some schists and gneisses, or on a still smaller scale in the well-known puckered green schist of the Gorner Grat. The supposed tree in gneiss exhibited in the Berne Museum is only a more hornblendic portion of the gneiss curled and drawn as above described. The idea that it was a tree-stem

* *Archives des Sciences*, vol. lxiv (1878), p. 120; *Mechanismus der Gebirgebildung* (1878) vol. ii, p. 213.

found favour because the gneiss was supposed to be a metamorphic sedimentary rock.

In the present state of Swiss stratigraphy, it would be a great convenience if the word *Flysch* were no longer used as a term in systematic stratigraphy, but retained in current language as descriptive of a very common lithological character. It seems to be applied to rocks which have been referred by different authors to every horizon from Trias, at any rate, to Tertiary inclusive, and it will be a long time before the exact age of the variously-altered black shales of the Alps shall have been determined.

In the Rhone Valley, near Vernayaz, we were shown what were considered to be three unconformable junctions of different ages, with a conglomerate at the base of each.

The oldest of these was included in the *Cornes Vertes*, a series of micaceous and chloritic schists of pre-Palæozoic, or perhaps, it was suggested, of Algonkian age. It consists of large rolled fragments and comminuted débris of gneissic rocks, itself having a superinduced schistosity which makes the harder included fragments, especially when chiefly felspar, look like eyes round which the more plastic matrix is moulded.

The next conglomerate formed the basement bed of the Carboniferous system, and the third was referred to the Trias; above it came various beds of Secondary and Tertiary age. It seemed to some of us, when examining this section, that sufficient account was not taken of the great faults which traversed it and somewhat vitiated the reasoning from the present relative position of the rocks.

Deformation in the Rocks.—From the observations above described we were prepared to admit the possibility of meeting with groups of rocks, whose general aspect was so much altered in structure, texture, and even in mineral and chemical composition by crushing, and its concomitant effects, that it would be difficult to identify the several representatives, except by following them through their gradual change, and where in isolated sections the only test of identity might be their syntelism, or constant recurrence of similar sequences. In our traverses we endeavoured to follow such changes of the constituents under the influence of pressure until the rocks were no longer to be recognised as the equivalents of the sediment which they represented in an altered state. This lithological change was gradual, and we found that the ordinary tests of sedimentary origin were sometimes not quite obliterated till long after the rock had approached in general appearance, and even in many details of structure, some of those which we have been accustomed to refer to the more ancient schists and gneisses. For instance, in some cases fossils were still recognisable in schists with longitudinal mullion structure, transverse puckering, and a considerable rearrangement of mineral constituents. Pebbles, which were of such a character as would

lead us to expect a spherical or ovoid form, were rolled out and elongated, and showed the general superinduced schistosity of the conglomerate in which they were embedded. Sandstones and grits were converted into massive quartzite, and where the original rock contained in addition to its siliceous grains a considerable quantity of aluminous material, it readily passed into siliceous schists.

As the rocks to which our attention was chiefly directed were referred to the Carboniferous or Poikilitic, we naturally recalled examples in which we were familiar with the kind of local variation in the sediment which we were called upon to accept in explanation of the differences in the character of the Swiss altered rocks, and having experienced no great inconvenience in the use of our old system, according to which we which we left stiff clays in the Thanet Sand, or found that the "Third Grit" consisted of thousands of feet of shale, we tried to avoid any side issues on questions of mere nomenclature, and to follow the evidence offered by our guides, even where it involved our calling a garnetiferous mica schist by the name of the series to which it was supposed to belong, viz., Trias quartzites; for why should not the altered siliceous sand of one area be of the same age as the altered sand full of aluminous and magnesian minerals of an adjoining area.

Here, however, the question arose, was it likely that the sediment did thus change in the direction required by the theory? and as the answer involves a knowledge of the palæophysiography of that part of Europe, which must be based on very wide and very detailed work, we can only recognise the difficulty and pass on to points on which we can offer more definite information.

In illustration of the above remarks, we lay on the table the following specimens:

1. Sand of the Rhone from near Vernayaz, derived first or second hand from gneissose rocks, and consisting of the same minerals in much the same state as those in the conglomerate close by.

2. Conglomerate at the base of the Carboniferous, Vernayaz, containing shaly portions full of carbonaceous matter, and schistose portions which are remanié gneiss.

3. The older conglomerate of Vernayaz mentioned above.

4. A gneissic-looking rock from near Brieg, with very siliceous eyes in places. This, we were told, is an altered conglomerate.

5. Gneiss with garnets, from Berisal.

6. Newer Gneiss with great felspar eyes, Simplon.

7. Older Gneiss, from near Gondo, without the eyes.

These specimens are in the Woodwardian Museum.

Now, in this series it will, we think, be generally admitted that the structure of all is due to mechanical deformation. But it may be expected that some will see evidence of the sedimentary original in specimens 1 to 3 only, that others will admit it in the case of 4, and perhaps of 5, while some will see in 6 only

a further stage in the same process. It is the old story. We have gneisses which can be recognised as such as long as the alternations of various mineral aggregates are small enough to be exhibited in any one section, but when the masses in which the granitoid structure entirely prevails or those in which the hornblendic or micaceous constituents predominate are of great thickness, then we hear of schists and amphibolites lapping round the granite ; yet the explanation is often suggested by the granite here and there putting on a gneissic character.

The microscope can show that there are interlocking crystals or rounded grains of crystalline minerals, but when these have been broken and crushed and displaced by subsequent movements it can rarely offer any evidence as to whether the rock was originally a granite, an arkose, or even a conglomerate. When an amphibolite schist is seen who can tell from an examination of the rock itself whether it is the hornblendic portion of a gneissic series or some intrusive basic rock of any age with superinduced schistosity ; and so also in the case of the mica schist it is not easy to say when we should call a rock a mica schist, and when it is only a fine micaceous gneiss. Sometimes the presence of frequent micaceous layers seems to have caused the rock to yield along them, and thus has spared the intermediate quartz and felspar bands.

On the flanks of such a mountain complex we have in later times the sediment derived from the granites, gneisses, amphibolites, and schists, and this sediment itself crushed and mylonized by subsequent earth movements. Who then shall tell a rolled out arkose belonging to the newer and sedimentary series from a crushed gneiss belonging to the older masses whose own origin, whether altered, eruptive, volcanic, even sedimentary, has been obscured by the change which time has wrought in them ?

When we are shown a granite or granitoid rock rolled out mechanically until the harder constituents are fractured and the fragments drawn from one another, while the soft parts are moulded into the interstices or dragged out into films, and in the same region are told that a similar looking gneissic or schistose rock is an arkose, or even a conglomerate of similar composition similarly treated, we cannot but grant the probability, nay, the certainty, that such things must occur in an area so grievously tormented as the Alps, yet to see the proof in any one section cannot be expected. The arkose of Innertkirchen was still an arkose, unless we prefer to call it a brecciated conglomerate, and it lay at the base of a sedimentary series which was only here and there altered by mechanical action, but always recognisable. So the difference between the three principal conglomerates of Vernayaz was to the naked eye sufficiently well marked. The oldest was most schistose and the newest contained the greatest variety of constituents, but all these rocks under the microscope show chiefly the constituents

of granites dragged out, broken, and deformed. The sand of the Rhone close by is much like the main mass of these rocks in composition, and if subjected to the same welding that the gneisses and many of the still obviously sedimentary rocks have undergone, must microscopically show the same jumble of parted crystals, moulded mica, and re-set base. Here again, what we did see helped us to accept the probability of much that we were told but did not see.

In some of the rocks, however, the mechanical deformation was not so remarkable as the mineral change. We saw the Rauchwacke losing much of its carbonate of lime and becoming cavernous or knobbly. We were shown by and by a magnesian rock consisting largely of mica with garnets or of hornblende with epidote, and were told that the magnesian silicates and what lime was wanted were in the earthy magnesian limestones from which those rocks were derived. The microscope can tell us nothing of the age or origin of these rocks, but their mineral composition is not inconsistent with the view that some of the garnetiferous mica schists and of the epidote-amphibole rocks may have been derived from a dolomitic series, with alternations of calcareous ferruginous shales, if we could only explain the process or trace the gradual change.

PART II.—By Dr. Hume.

Meyringen—Innertkirchen.—Hitherto the age of the limestone dominating the Haslithal and forming the bold precipices so familiar to those visiting Meyringen, has been referred almost unanimously to the Malm or Upper Jurassic. Last year M. Golliez published a new theory in the official Livret-Guide of the Zurich Congress, regarding the whole of them as Triassic on the following grounds:

1. They are said to bear a strong resemblance to the Triassic limestone of Briançon and the Valais.

2. They contain intercalations of quartzite, gypsum, and sandy dolomite.

3. The relations to the Dogger are said to be such as might be expected of Triassic beds.

Fig. 1 A illustrates the general view as explained by Prof. Baltzer; and Fig. 1 B Prof. Golliez's theory.

The divisions have been combined from a study of two sections, both easily reached from Innertkirchen. The first, the Rothfluh, in the Urbachthal, at the foot of the Engelhörner; the second, the Spisswand, a precipitous cliff rising at the back of the Hof Hôtel to the right of the Aar valley. All the fossils mentioned were obtained by members of our party, and the description is from notes taken on the spot.

(*a*) is the limestone under discussion, which bounds the Haslithal, and is the rock through which the Aar has cut its famous gorge.

(*b*) Highly metamorphosed yellow-grey limestones and slates = Birmensdorferschichten, often very finely banded, and generally rich in sericite.

(*c*) The Eisenoolit, a highly ferruginous oolitic rock, which at the Spisswand contains Belemnites and a doubtful *Terebratula*.

(*d*) Reddish brown sandy limestone with *Ammonites Parkinsoni*, *Amm. Humphresianus*, imperfect Belemnites, and Lamellibranchs.

(*e*) A series of shales referred to the Lias. On the Spisswand below these shales is a pisolitic limestone, which yielded *Gryphæa arcuata*, *Amm. macrocephalus tumidus*, *Terebratula ferovalis*, and *Pecten glaber*. *c* to *e* thus represent Dogger and Lias.

(*f*) Red brown and greenish dolomitic beds, with intercalations of sandstone, considered by most writers as Triassic.

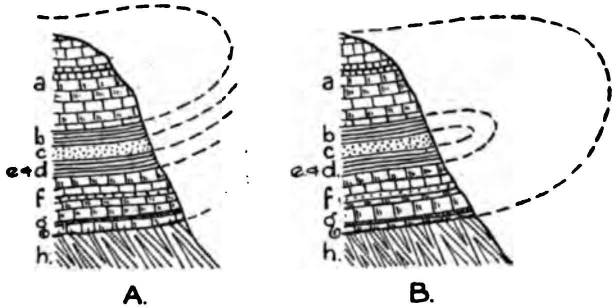


FIG. 1.—SECTION NEAR INNERTKIRCHEN.

(*g*) Röthidolomit, here a grey, compact dolomitic limestone.

(*h*) Muscovite gneisses with two felspars = Innertkirchen gneiss. At first sight, the limestone overlying the Dogger and Lias would be considered as younger or of Upper Jurassic age, but the considerable folding to which all the strata have been subject renders ordinary methods of comparison useless. It is universally admitted that the beds under discussion form part of a great overfold; but whereas Prof. Baltzer submits that great denudation has taken place, removing the superincumbent Triassic strata, Prof. Golliez holds that the return curve takes place at the Eisenoolit *c*, and that *d* and *e* occur above *c* in reverse order, the great thickness of limestone above representing the dolomitic beds, *f*, which are the accepted representatives of the Trias in this neighbourhood.

If this be so, and the Dogger and Lias are folded back over the Eisenoolit, they must be represented by the now highly altered

Birmensdorferschichten, to which Prof. Golliez does not refer. Moesch* has lately shown that the few fossils met with have quite a distinct character, *Ammonites plicatilis* and *Amm. arolicum* being the commoner forms.

Prof. Golliez urges, in support of his view, that these beds are similar to the Triassic beds of the immediate surroundings; but we did not see anywhere in the Haslithal the distinctive porous dolomite, the cornieule, or rauchwacké, which on the Furka, at Zermatt, and on the Simplon, forms such a characteristic member of the Triassic strata. The rocks of that area rather recall the Hochgebirgskalk (Jurassic) farther to the east, or the Malm series which plays so important a part in the chains to the south-west of the Lake of Thoune.

Can the dolomitic beds which form the acknowledged Trias at the base represent the altered limestone which is said to be their equivalent above? While freely granting the possibility of rapid alteration in the characteristics of marine strata, it does seem somewhat difficult to admit that one limb of the overfolded synclinal can consist mainly of dolomite and sandstone, whilst the other displays an overwhelming predominance of limestone, or "marbres."

Moreover, we failed to find in the Aar gorge the intercalations of quartzite, gypsum, and sandy dolomite noticed by Prof. Golliez. At this locality the limestone was very homogeneous, and in general effervesced freely in cold hydrochloric acid. Prof. Golliez has, however, noted an arkose, and Prof. Baltzer found one locality where the behaviour pointed to the occurrence of a dolomite, but holds that a slight roll would be sufficient to bring up the Trias at this point without in any way affecting the main argument. The relations to the Dogger are far more suggestive of Jurassic than of Triassic beds.

Moesch (*loc. cit.*) has also added fresh palæontological facts which strengthen our belief in the validity of the older views regarding the age of these limestones.

Zermatt—Simplon.—It has been already shown in an earlier part of this paper that considerable differences of opinion have arisen regarding the character and extent of the strata (assumed by some to be Triassic), met with to the north of the Bernese Alps, and it is, therefore, with interest that we turn to an examination of those rocks, which, by the greater number of writers, have been admitted to be truly Triassic.

As an example, we would refer to the Zermatt district. An excellent section displayed above the railway close to Zermatt station, gives the key to the interpretation of the complex foldings displayed between this locality and the Gornergrat.

1. The rock exposed near the village itself is of a deep green colour, and markedly schistose in character, to which properties it

* *Beitr. z. Geol. Karte der Schweiz.* Lief xxiv, p. 148.

owes its names of pierre-verte, chlorit-schiste, or pietre verdi, commonly applied to it by Swiss geologists. No fossiliferous bands occur in connection with it, and in adopting a Permian or Carboniferous age for these beds, our guide, Prof. Golliez, has entirely accepted the views of Zaccagna. The latter holds that, in the Ligurian Alps, a broad anticlinal exists, of which Carboniferous strata form the core, these being directly and concordantly overlain by the pietre verdi, which themselves are flanked by younger Triassic rocks.

2. Near the first tunnel met with after leaving Zermatt, the pietre verdi suddenly cease, and are replaced by a series of beds dipping at a considerable angle to the south-east. The lowermost of these consist mainly of grits and quartzites interstratified with a few layers of altered limestone, or cipollino.

3. The siliceous rocks give place to dolomites, gypsum, and carbonaceous marls, including a soft calcareous band, classed by Prof. Golliez as rauchwacke, but differing considerably from the porous dolomitic rauchwacke displayed on the Gelbewand above the Gorner Glacier.

Nos. 2 and 3 have a thickness of only about 30 feet at this point, being then replaced by 4, a dark grey highly calcareous schistose rock, containing much mica and a certain amount of quartz. This is known as "marbres phylliteux." The first lesson that can be gathered from this section is the gradual change in the rock-constitution, in the ascending series there being first a succession of siliceous by dolomitic, and then of dolomitic by purely calcareous members.

No. 4 is displayed for a distance of over a kilometre along the railway, until (at a point where a torrent descending from the lower slopes of the Weisshorn range has cut a deep channel) a series of beds is exposed which exhibits in reverse order the same sequence as that already observed. The dip remains the same as before as regards direction, but is steeper in inclination, and the older strata appear to overlie the younger. The explanation is that we are here dealing with the synclinal portion of a highly-inclined isoclinal fold, the axis-plane of which is dipping on an average 45° to the south-east.

Ascending the torrent the marbres phylliteux are succeeded by a beautiful rose marble, differing from many of the marbles associated with more ancient rocks in the absence of a saccharoidal crystalline structure.

3. A band of dolomitic red marl and gypsum is separated from No. 4 by a thin layer (only a few inches in width) of yellow and red-brown shales, containing an almost colourless mineral, with very strong absorption, which has been identified as glaucophane. Chlorite is also present in some quantity.

2. A chloritic quartzite forms a steeper slope, the whole being capped by a series of micaceous schists, which are taken as representing the pietre verdi at this locality.

In ascending from Zermatt to the Gornergrat, infolded Triassic beds are repeatedly met with, differing considerably in external appearance according as mica is present or absent. The following table shows the general succession from below upwards:

1. Pietre veidi=Permian of Zaccagna.

Type.	*Without mica.*	*With mica.*
2. Siliceous	Massive white quartzites	Silvery micaceous quartzites.
3. Dolomitic	Dolomite, with gypsum, etc.	Micaceous Rauchwacke.
4. Calcareous	Impure marbles and marbres phylliteux	Micaceous cipollinos and schistes lustrés.

2, 3, and 4 are, as above stated, referred to the Trias. The truth of this succession is further illustrated on the Simplon, both between Eisten and Bérisal, and near Refuge V. Also on this pass the relationships the above rocks to the older metamorphic series is also revealed, though little stress can be laid on the evidence here. Below the Triassic quartzites at Bérisal, north of the Hospice, and below cipollinos at Alte Caserne, south of the Hospice follow (1) mica schists, frequently garnetiferous, and of normal character. These form only a comparatively thin band as a separate member, though occasionally rocks of similar nature alternate with the next series.

2. A considerable thickness of dark-green hornblende-schists underlies No. 1, and though varying considerably in texture, and frequently interlaminated with bands of mica-schist, it nevertheless forms a distinct lithological zone.

3. The core of the Simplon axis is mainly gneissose, the gneiss in its upper layers being often most beautifully banded, and containing large felspathic eyes, whilst in the lower portions the rock has a more definite granitic structure. The first type has received the name of Superior Gneiss, or the gneiss of Monte Leone, the second Inferior Gneiss, or Antigorio-gneiss.

By combining the results from Zermatt and the Simplon, we obtain the following succession for the eastern portion of the Pennine Alps, commencing from above:

1. Limestones, Cipollinos, Schistes lustrés, or Marbres phylliteux.
2. Rauchwacke (Corgnieule), Dolomite and Gypsum.
3. Quartzites (massive or micaceous).

Nos. 2 and 3 are not present in the Alte Caserne section.

4. Pietre verdi (with Serpentine dykes), possibly Permian. Not noticed by us on the Simplon.
5. Garnetiferous Mica-Schists.
6. Amphibolites.
7. Ribboned or Banded Gneiss of Monte Leone.
8. Coarsely granitic Gneiss of Antigorio.

PART III.—By Mr. Monckton.

Morcote.—The diagram, Fig. 2, illustrates the explanation of the celebrated Morcote section, given to us by our directors, MM. Golliez and Lugeon.*

Morcote is a small town on the shore of the Lake of Lugano, and on the road from that place to Melide one has a good opportunity of studying the series of igneous rocks shown in the diagram.

Firstly, we find a series of schists along the shore of the lake.

Secondly, there is a great mass of porphyrite resting upon the schist series, and in at least one place a large vein passes up through the schist to the porphyrite.

Thirdly, there are masses, probably laccolites of quartz felsite, and numerous veins pass up to them through both the schist and the porphyrite.

We have, therefore, here igneous rocks of two different ages, both of which not improbably belong to the Carboniferous or Permian periods.

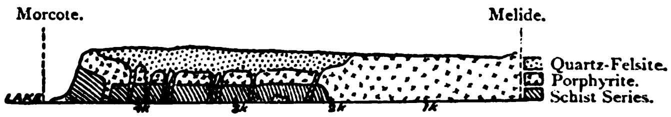


Fig. 2.—Section from Morcote to Melide—Lake of Lugano.

Starting from Morcote, we saw just outside the town, on the Melide road, an exposure of the porphyrite, which we were told was part of the large vein shown in the diagram (Fig. 2). It is a hard, close-grained, blueish-grey rock, consisting of a ground mass of quartz and felspar with porphyritic crystals of plagioclase much altered. There is very little porphyritic quartz, but a good many flakes of a pleochroic green mineral, usually, we think, biotite, but occasionally hornblende, in both cases much altered. A little iron oxide is associated with the green mineral.

The porphyrite vein was seen to be in contact with a micaceous schist which continues at the side of the road for about 200 yards. and we then came to a vein of reddish quartz felsite, and soon after we noted a second similar vein at the milestone four kilometres from Melide. A little farther on we saw two more. A microsection from one of them shows that the porphyritic minerals are quartz, in large, very clear grains, plagioclase, a little orthoclase, and a green pleochroic mineral, apparently altered biotite. There are a few specks of iron oxide associated with the green mineral, the change in which is similar to that noted in the porphyrite. The plagioclase is fairly well preserved, much better

* For a full account of this section and its petrology, see Dr. C. Schmidt in the *Livret Guide*, pl. viii, Fig. 1, and in *Ecclog. Geo. Helvet*, vol. ii (1890-92), p. 1, and Michel Levy, *Bull. Soc. Geol.*, 3rd series, t. i, p. 464 (1873), and t. iv, p. 111 (1875).

than in the porphyrite; one large crystal has become broken up into small fragments, which are separated from one another by intrusion of the ground mass. The ground mass is very fine grained, and seems to be composed of quartz and felspar.

A section cut from the edge of one of these veins shows a more basic rock than in the middle, with a speckled structure close to the edge, flakes of white mica are scattered through the slide which Prof. Bonney suggests are very probably fragmental and derived from the schists.

The rock through which these veins pass is a very micaceous schist, but it changes in character a little nearer Melide, and is then a hard, dark grey, close-grained rock, with indistinct gneissose structure. The microscope shows quartz grains crowded together, forming a ground mass with a felspar very much altered, a ferro magnesian mineral associated with a little iron oxide so much altered as not to be recognisable. It is succeeded by more schists, and at about $3\frac{1}{4}$ kilometres from Melide we find the following succession from south to north along the road.

1. Mica schist with much quartz.
2. White quartz-felsite vein, 18 feet.
3. Black rock forming edge of vein, much decayed, 3 feet.
4. Black rock, apparently altered schist, 1 foot.
5. Schist, 4 feet.
6. White quartz felsite, 18 feet.
7. Decayed earthy bed, $\frac{1}{3}$ foot.
8. Crumpled schists.

A little farther north we find more gneissose rock belonging to the schist series, and forming a point which projects slightly into the lake.

We then pass more schists with at least two more quartz felsite veins, and at the Villa Isidora, two kilometres from Melide, we come to a great talus of red and black porphyrite, and soon after to that rock *in situ* at the roadside, it having come down to the level of the lake. It varies considerably in character, and is always much altered and decayed.

St. Gothard.—The section, Fig. 3, gives a general idea of the geology of the top of the St. Gothard Pass, between Goschenen and Airolo, which places are at the ends of the St. Gothard Tunnel. A series of specimens from the tunnel is preserved in the Natural History Museum, and Mr. Fletcher, with his usual kindness, allowed us to examine them, and compare them with those we collected at the surface. In any such comparison it must not be forgotten that during a considerable part of its length the tunnel is some distance reaching a maximum of two miles to the east of the road.*

Starting from Airolo, we find in the tunnel a brown, yellow,

* An excellent account of the Geology of St. Gothard, by Karl von Fritsch, will be found in vol. xv of the *Beitroge zur Geol. Karte der Schweiz.*

and white softish dolomitic rock called Rauchwacke, which extends for some 80 metres along the tunnel. The specimen, No. 14, at 78 metres, is a breccia, with fragments of greenish schist. We did not find it at the surface, but it may be compared with the breccia in the ravine Val Canaria, some 4 kilometres to the north-east, described by Prof. Bonney.*

As the stratification here appears to be nearly vertical, the question arises whether this breccia is at the top or at the bottom of the Rauchwacke, and, after a careful consideration of the evidence, we are inclined to think that it is at the bottom of that series, and that its component fragments are in all probability derived from the schists now exposed in the St. Gothard to the north. In this conclusion, however, we find ourselves at variance with some able geologists.

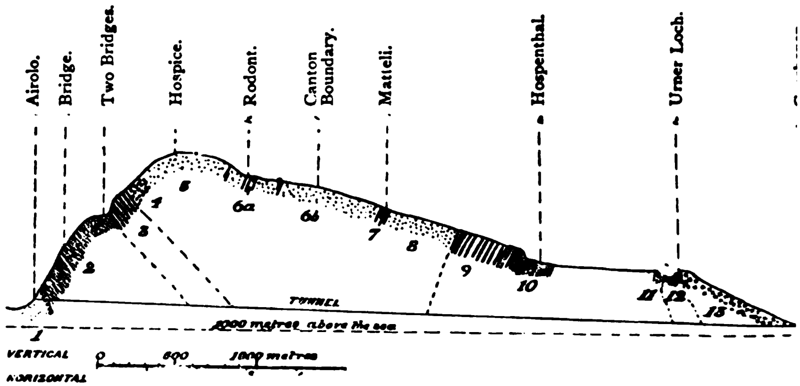


FIG. 3.—SECTION THROUGH THE ST. GOTHARD.

At about 83 metres from its mouth the tunnel passes from the Rauchwacke into schists, and on the St. Gothard road we find ourselves on the schists as soon as we are out of Airolo. The road mounts up through them by a series of zig-zags, and there are many small sections. The schist is light coloured, often full of garnets, and with much mica, black and white. Here and there actinolite crystals in radial bunches occur.

At the top of the first zig-zags we enter a little valley, and the road crosses the river which flows down the pass. On the west of this river there is a section in green hornblende schist, and above are more garnetiferous mica schists. There is a distinct dip to the north in the foliation of these schists.

Near a small house opposite Motta di Dendro, at a level of 1,694 metres above the sea, we noted a good deal of hornblende

* *Quart. Journ. Geol. Soc.* (1890), vol. xlvi, pp. 209, 212, 213.

schist, which is folded into sharply pointed folds, always with a northern dip.

This rock contains numerous garnets up to ½ inch in diameter, and the hornblende schist with some mica schist continues as far as a place where two bridges cross the torrent at a level of rather more than 1,700 metres. There we found a few beds of quartzite in the schist, and the series ends. These, from the edge of the Rauchwacke, are the Tremola Schists of Prof. Bonney.*

He thinks that the association of these variable and well-marked bands is due to original difference of mineral composition, and points to some kind of stratification, and is further of opinion that they are of pre-carboniferous age. Dr. A. Baltzer, on the other hand, thinks that they should be referred to the Lias and Dogger, and he accordingly draws a synclinal between Airolo and the top of the St. Gothard, making the Rauchwacke, which is admittedly of Triassic age, older than the Tremola Schists. Dr. C. Schmidt practically agrees, but draws a double synclinal.†

Our acquaintance with the area in question is scarcely sufficient to enable us to venture on any very decided opinion on this question, but so far as we are able to judge we are inclined to favour the view that the Tremola schists are older than the Rauchwacke, and that we are passing from newer into older formations as we ascend from Airolo to the two bridges.

Above the two bridges the road mounts by more zig-zags, and we find a different series consisting of dark coloured gneiss often with garnets, and in places with dark green hornblende rock. These are No. 3 of Fig. 3, and answer to the Sorescia Gneiss of Dr. F. M. Stapff.‡

We next come to a comparatively white rock, No. 4 in Fig. 3, and the line between the dark and light coloured rocks is very well marked across the ravine up which we are ascending, and after some climbing we obtained hand specimens, one of which furnished a micro-section showing the actual junction of the two rocks. We also took specimens from the two rocks at a little distance from the junction, and have micro-sections from them also.

The dark coloured gneiss is composed of quartz in small grains, brown and white mica, and a quartz-felspar mosaic, and close to the junction there is a good deal of felspar, apparently both orthoclase and a clear striped felspar in very small fragments. The actual junction is marked by a line of flakes and patches of flakes of dark mica.

The white rock is formed of clear grains of quartz and large crystals of orthoclase and plagioclase, usually very full of inclusions.

* *Quart. Journ. Geol. Soc.*, vol. xlii (1886); *Proc.*, pp. 71-109.
† *Livret Guide*, p. 168, Plate viii, fig 1; Plate ix, fig. 3.
‡ *Geol. Mag.* (1892), Dec. III., vol. ix, p. 6.

There is a little white mica. Both rocks have apparently been more or less affected by crushing. The dark mica in the dark-coloured rock is of a somewhat peculiar aspect, possibly the result of contact metamorphism, but it is not easy to say how much is due to that cause and how much to the subsequent crushing; perhaps we may look upon the quartz-feltpar mosaic, which is a feature of the dark-coloured rock, as mainly the result of the crushing.

The white rock is a granite, with but little sign of subsequent alteration, but as we proceed towards the Hospice we find the rock becoming distinctly gneissose in character (5 in Fig. 3), and eventually, close to the Hospice, we find a quarry in the rock known as the Fibbia Gneiss. We were unable to discover the exact line of division between the rocks 4 and 5, and according to Dr. Stapff there is a gradual transition from one into the other.*

The dark-coloured gneiss, No. 3, continues further to the north in the tunnel than in the road, which is here 600 metres west of the tunnel.

The Fibbia Gneiss (5 in Fig. 3) consists of quartz, which is sometimes in large grains, at others in minute fragments closely packed in masses with white mica, probably the result of crushing, of orthoclase in large crystals, with a little plagioclase, and of biotite and muscovite. The Fibbia Gneiss is believed by Prof. Bonney to be an intrusive granite which has been subsequently modified by pressure.†

It continues some way down the northern side of the pass, but at a level of 2,018 metres, where the road crosses the river Reuss, the rock becomes schistose, and intercalations of dark-coloured rock are frequent (No. 6*a* in Fig. 3), but are not, as far as we saw, of very great extent. There are several of these dark patches at Rodont, a ruined house at a level of 1,976 metres. Under the microscope the rock of the dark patches is seen to be composed of quartz grains closely packed together, and of dark and white mica drawn out in lines. A little iron oxide is scattered through the rock. The felspar is, we think, mostly orthoclase but a striped felspar also occurs. There are some flakes of a green mineral, probably hornblende, some epidote and secondary minerals.

In this dark-coloured gneiss there are intercalations of white gneiss, and close to the wall of the ruin the white and green rocks are intermingled in streaks and patches in the remarkable fashion shown in Plate II, B, which is from a photo taken by one of us on September 21st, 1894. The gneiss from the bridge over the Reuss to Rodont, marked 6*a* in Fig. 3, is the micaceous Guspis Gneiss of Dr. Stapff, and he believes it to be the oldest or deepest

* *Geol. Mag.*, Dec. III, vol. ix (1892), p. 20.
† *Quart. Journ. Geol. Soc.*, vol. xlii (1886), *Proc.*, p. 71.

A.—DARK-COLOURED BANDS IN WHITE GNEISS, MATTELO.

B.—WHITE VEINS IN DARK GREY GNEISS, RODONT.

of the crystalline rocks of the St. Gothard.* Below Rodont the prevailing rock is still a light coloured gneiss (*6b* of Fig. 3), but here and there patches of dark gneiss occur. There is one at a hump of rock on the east of the road, a little below the ruined house, and still farther down at a height of 1950 metres, where the road is cut through a projecting point of rock, quartz bands and dark-coloured patches occur. The line between the dark and the light coloured rock is fairly sharp, but the trend of the foliation in both is in the same direction. Under the microscope, the dark-coloured gneiss is seen to be of much the same character as the gneiss No. 3, and the dark patches at Rodont. The white gneiss consists of quartz, orthoclase, a little plagioclase, and bundles of flakes of light and dark mica. The middle of the plagioclase crystals is usually full of enclosures, whilst the edges are clear. In the large patches of orthoclase are enclosed quartz, muscovite, and plagioclase.

This rock is a porphyritic gneiss, and differs somewhat in appearance from the Fibbia Gneiss.

Some distance lower down we cross the boundary of Cantons Ticino and Uri, and enter a long, narrow valley, at the lower end of which there is a small house named Matteli. Above this house there are intercalations of a greenish rock, No. 7 of Fig. 3, in the light coloured gneiss; they are in the form of narrow, parallel bands, with a N.E. and S.W. trend. Plate II, A, from a photograph taken on September 21st, 1894, shows the way in which they occur better than any explanation in words.

We now enter a second long, narrow valley, called Gamsboden, and about 500 metres down it there is a small mass of schist in the white gneiss, and near the lower end of the Gamsboden the white gneiss No. 8 comes to an end. In the tunnel it does not extend quite so far north as at the surface. This northern portion of the white gneiss, *6b*, 7, 8 in Fig. 3, is the Gamsboden Gneiss of Dr. Stapff. Numerous views as to the origin of the dark and light coloured gneiss have been held by geologists; but the best opinion is, we think, that the dark coloured gneiss is the older rock, that the white rock is a granite which was intruded into the dark coloured rock, the white rock in the photographs (Plate II) being thus veins of granite, and that the whole has since been modified and more or less changed by pressure.

At the lower end of the Gamsboden the road enters a ravine, through which the Reuss flows down to Hospenthal. At its upper end there is a dark-grey gneiss, 9, not unlike that on the south of the pass, 3 in Fig. 3, but as we descend we find the gneiss is mingled with rocks of the character of a schist, and eventually we find ourselves in the Hospenthal Schists, No. 10, which continue down into the Urseren Valley. We do not find it easy to say exactly where the gneiss ends and the schists begin.

* *Loc. cit.*, p. 17.

We have now crossed the massif of the St. Gothard, and we have seen that it consists of a central mass of white gneiss, probably originally a granite, at each side of which we find a grey or dark-coloured gneiss (3 and 9 of Fig. 3), and outside the grey gneiss schists. On the south at Airolo we find Triassic Rauchwacke adjoining the schists, and also on the north of the Urseren valley, we find a little Triassic Rauchwacke as well as beds of Jurassic age.

The dip throughout is very high, and there is a very distinct fan structure, *i. e.*, the beds south of the Hospice dip north, and the beds to the north dip south, those in the centre being practically perpendicular.

At Hospenthal the road turns with a right angle to Andermatt, and as it would not be easy to indicate this on the section (Fig. 3), we have left a blank at this point. At Andermatt the road turns again north, and we reach the celebrated Altkirche section. A small quarry furnished us with specimens of Altkirche marble, the age of which is much disputed. A very full account of the section has been given by Professor Bonney.* Dr. Stapff's views will be found in *The Geological Magazine*,† and the views of other Swiss geologists will be found in *The Livret Guide*.‡

Passing through the tunnel called Urnerloch, we enter the great ravine of Schellingen, which is cut through a light-coloured rock, with a more or less granitoid appearance, called protogine. In it are numerous veins of aplite, and here and there intercalations of dark-coloured gneiss occur. This forms part of the Finsteraarhorn massif.

In the tunnel the protogine begins at 2,000 metres from the northern end, and continues to Goschenen, the station at that end of the tunnel.

* *Quart. Journ. Geol. Soc.*, vol. xlvi (1890), p. 191; vol. l (1894), p. 288.
† *Loc. cit.* and 1894, p. 152.
‡ Pp. 151, 166.

ON THE ANALYSIS OF OOLITIC STRUCTURE.

By GEO. F. HARRIS, F.G.S.

[*Read 4th January, 1895.*]

IT is not the object of this paper to discuss the origin of oolite, or of oolitic granules; neither will any attempt be made to describe in detail the structure of the material which in so many cases holds the granules together, or to compile a bibliography. The author believes that a more rigorous examination of the granules themselves than has hitherto been attempted is very desirable, and it is his purpose now to make an essay in that direction. There has been a general tendency on the part of authors to confine their descriptions to oolites collected over a very limited area, and with the aid of but a small number of specimens.

Oolitic granules have often been alluded to as though they all had a common origin. It does not seem to have been recognised that there are several distinct types of granules, which are, to a large extent, peculiar to the formations in which they are found, or are local in their distribution. The author cannot hope to fully discuss this point on the present occasion, though the particulars given will be seen to trend in the direction of its elucidation.

It is well known that oolitic structure is found in rocks of every age, and is not by any means confined to special formations. It occurs in fresh-water deposits as well as marine. Oolitic granules are being formed at the present day in many parts of the world—in the sea, in rivers, and in lakes. Something very like them, if, indeed, not identical in essential structure, occurs as calculi in animals, in the kitchen kettle where hard water is used, and under other remarkable circumstances. They have been produced artificially times without number by purely chemical means, and they are known at the present day to be forming by organic agency on the large scale other than that just indicated.

It may be taken for granted that nearly all the oolitic granules found in rocks, except those of modern formation, have been more or less changed by the usual agents accredited with mineral alteration underground; and it seems to be equally clear that much of the "secondary" structure thus induced has been mistaken by some authors for original. It is impossible to assign any limit to this alteration, which may obliterate the granules almost

beyond recognition. The following instances of extreme modification may, however, be noticed. The granules may be changed from calcite, or aragonite into iron, silica, or carbonaceous matter; by dynamical means they may be sheared until they and the material in which they exist are made to assume quite a schistose aspect, and cases are on record where an oolite limestone passes into schist containing mica, etc. Such alterations as these are patent to every one who studies the subject, and they can usually be detected with facility. Other modifications are not so easily made out, and demand careful attention. The precise effects due, for instance, to the gradual incorporation of granules into their matrix, whereby it is occasionally difficult to define the boundary between the circumference of any particular granule and the flood of matrix surrounding it, are very little understood. It would seem as though the granules are sometimes "fused" or partially "melted" in the matrix, so subtle is the transition from one to the other. Then we have cases, somewhat akin to the last-mentioned, in which the granules are caught up in a system of calcite crystals—the granules behaving as though they formed part of the crystals, so that the regular cleavage lines of the latter, instead of being obstructed by the former, continue through them, the whole being, as the microscope shows, in optical continuity. A ghost of the original granules is all that remains. Here we have an instance of the original mineral matter, nuclei and all, having been replaced, molecule by molecule, by calcite in close relationship with the calcite matrix.

Interesting it is, too, to observe the extreme vicissitudes which the granules in some oolites have undergone. They appear first to have been partially decomposed, and then, after having been on the verge of complete destruction, circumstances have altered in their favour; their miserable remnants were gathered together, re-hardened, and in some few cases replaced, by calcite and set in a matrix of the same mineral. The phenomena accompanying this alteration were as remarkable as effective. In not a few instances the author has observed that in attempting to re-form the granules after they had been considerably decomposed, the small calcite crystals engaged in the work were so disposed as to simulate that which was altogether destroyed. For example, where decomposition led to the formation of a hole in the radiating aggregate of prisms springing from the nucleus, when the granule was undergoing restoration this hole was not plugged up by a shapeless mass of calcite, but the mineral matter took root, so to speak, on the ragged edges of the truncated prisms and perpetuated the radiating prismatic structure until the gap was filled. Partial decomposition with successive re-crystallisation may be shown to have taken place several times in some oolitic granules. Mr. Sorby has demonstrated* how they may re-crystallise

* Sorby, *Quart. Journ. Geol. Soc.*, vol. xxxv. (1879), p. 75.

within and form aggregates of calcite granules, all structure but the outer form being lost.

Apart from the total replacement of the original by some other substance, there are modifications induced by mineral colouration, by which some granules are rendered semi-opaque, and their structure consequently much obliterated. Occasionally two or more of them have been employed as a compound nucleus of a much larger granule, though this appearance of a compound nucleus is not always real, as will be seen later on. The phenomenon which the author calls inter-penetration—where one granule is partially embedded in another—is observed but rarely, except in certain oolites presently to be named.

In regard to nuclei, these will be described under the headings of the various granules dealt with, but it may be noted that they are frequently less durable than the coats enveloping them, and on decomposing are apt to affect a few of the successive coats lying next to them. The decomposition also has a tendency, under such circumstances, to follow along or between the radiating prisms (where these exist), and not infrequently the disposition of the innermost concentric lineations is taken advantage of by it. The result is the formation of a more or less shapeless mass of semi-opaque material of very unsatisfactory appearance.

Turning to the enveloping material of the granules which is here called the "coating," this will be described in much detail in the following pages; and bearing in mind the interest created in recent years in the discovery of tubules by Mr. E. D. Wethered* in certain Jurassic pisolites, the author has rigorously searched for such in the oolites examined, and not altogether without favourable results, at least one oolite† being shown to possess tubules. The author has pledged himself not to discuss the origin of oolite, and he is therefore precluded from expressing an opinion as to the precise nature of these. He feels it incumbent on him, however, to state his conviction that many of the structures found in granules and spherules and referred to by the last-mentioned author as tubules, are not tubules at all. If such appearances were admitted as tubules, almost every oolite examined might be said to exhibit tubular structure.

The method of description adopted is to commence with granules of modern formation, as they have been least altered, and thus afford excellent standards of comparison; the circumstances under which they are found will also be touched upon. Then follow the Jurassic oolites, not in exact chronological order, and so on to the oolite of the Ordovician.

* E. D. Wethered, *Geol. Mag.*, n.s. dec. III, vol. vi (1889), page 196.

† Since this paper was read, Mr. Wethered has described the occurrence of tubules in the granules of many oolites, in a paper not yet published (26th April, 1895).

OOLITIC SAND OF MODERN FORMATION, PYRAMID LAKE, NEVADA.

Mr. I. C. Russell, of the United States Geological Survey, has, with others, notified* the occurrence of sand having oolitic structure, now forming amongst "The Needles" of Pyramid Lake, Nevada. He remarks that the grains are "formed of concentric layers of carbonate of lime which is being deposited near where the warm springs rise in the shallow margin of the lake. In places these grains have increased by continual accretion until they are a quarter-of-an-inch or more in diameter, and form gravel or pisolite. In a few localities this material has been cemented into a solid rock, and forms an oolitic limestone sufficiently compact to receive a polish. . . . The tufa forming 'The Needles' is grey in tone, with a light coloured band ten or twelve feet broad at the base, consisting of a coating of very recent calcareous deposit similar to that forming the oolitic sands, but probably not dependent on spring action. On the cliffs the nucleus about which the lime crystallised was immovable, and became coated with a continuous layer of calcium carbonate; on the beach the sands were washed about by the waves, and grew into little spheres of polished marble."

In another place Mr. Russell states,† after examination with the microscope, that the spherical form of the grains and the uniform thickness of the concentric layers evidently indicates that the kernels were in motion during the slow deposition of the concentric shells of which they are principally composed, though we are not obliged to agree with him on that point. He shows that these oolitic sands prevail over the entire area covered by the quaternary Lake Lahontan.

I am the fortunate possessor of a quantity of this oolitic sand collected by Mr. Russell during his geological survey of that part of Nevada, which was kindly given to me (through Mr. Merrill) by the authorities of the United States National Museum on the occasion of a visit to America in 1891. Sections have been cut for microscopic examination, and I hope to show that these present many points of interest in laying down facts concerning oolitic structure. I trust that my remarks may be accepted as a worthy supplement to the excellent field-work of the American geologist alluded to. Before describing their appearance under the microscope, it will be well to say something concerning the outward appearance of these granules or spherules.

They are for the most part irregularly ovoid or sub-angular in shape, but several are perfect spheres. Not a few are compound granules; one specimen on the table is made of as many as 13 distinct granules, over the whole of which a mantle of carbonate

* "Geological History of Lake Lahontan," *Mon. U.S. Geol. Surv*, vol. xi (1885), p. 61.
† *Op. cit.*, p. 168.

of lime has been thrown, keeping them together. This compound granule is not half the size of many of the solitary pisolite spherules amongst which it was found. It must not be confounded with those specimens in which several spherules have been cemented together by a matrix of calcareous tufa. The surfaces of nearly all are slightly polished, no doubt by the rolling action already referred to. Nevertheless, it does not appear that the attrition has removed much of the original outer substance of the granules, and some of them seem not to have been worn at all. In size, the solitary grains vary from minute pieces not larger than a small pin's head up to large spherules 8 mm. in diameter.

In thin sections under the microscope (Plate III, fig. 1) the nuclei are as a rule unrecognisable, consisting of a nebulous patch merging insensibly into the layers wrapping around it. Under $\frac{1}{4}$-inch objective it is seen to contain minute irregular patches, rather darker in tint than the remainder of the nucleus. Rarely, a quartzose sand grain constitutes the nucleus. Thin layers of carbonate of lime are regularly and concentrically disposed around the nucleus, and range in tint from pure white through light yellow to dark brown, with a general tendency to zonal structure. The lighter zones consist of extremely minute crystals of what are most probably aragonite, polarising in brilliant colours. Here and there the abnormal development of aggregates of these minute crystals has interfered somewhat with the regular disposition of the darker concentric layers. The latter, under a $\frac{1}{4}$-inch power, are for the most part ill-defined, the zonal boundaries being hazy and graduating into the lighter layers; but exceptions exist, and at irregular intervals sharply marked thread-like concentric lineations occur, which seem to denote resting places, or to have formed foundations whereon crystals belonging to the light zones were laid down. The lineations are rather remarkable, and look like little tubes in certain places. On comparing them with true tubules, presently to be described in another oolitic sand, I have come to the conclusion that they are not in reality tubules, however. The structure from one set of concentric lineations to another in the outer zones of the granules is noteworthy, and may be briefly described as follows (Plate III, fig. 2): On the convex side of a set of these lineations a number of clear crystals have formed, presenting a broad base and tapering towards the outside. On them are multitudes of minute granular crystals, and these large and small crystals constitute a "crystalline zone." Passing outwards, we note that the granular crystals become more indistinct, then semi-opaque—which character becomes more and more accentuated until the next set of concentric lineations is reached—thus forming a dark zone. This structure is best defined in the layers towards the outside of the granules.

Dealing more particularly with what I have called the crystalline zones, it may be noted that these vary in thickness on being traced round, and in some granules they are practically lenticular; the successive crystalline zones frequently have a greater development in one direction in a granule than in others. They are the only parts of the granules which distinctly possess radial structure, and this latter is not marked in many of them. The apparent radiation is due to the crystals being arranged in prisms, all of which converge on the nucleus. In addition to this, the yellow and less crystalline zones are permeated by minute irregular and discontinuous dark veins, which, locally, resemble main streams with their tributaries as depicted on maps. These veins have no connection whatever with the concentric lineations referred to; they rather suggest relationship with the dark boundaries of the components of the crystalline zones with which, indeed, they are sometimes conterminous. There seems to be very little doubt that had crystals formed to the same extent in the darker zones these veins would have assisted in regulating the disposition of the crystals, or *vice versa*. In the outer coatings of the granules the dark concentric lineations are broken up by grey lines running across them, often very close together. In some instances these minute partitions are confined to two contiguous lineations, but in others they traverse several of them.

It must be remembered that we are dealing with perfectly fresh oolitic granules, which have not been subjected in any way to secondary alteration. Nevertheless, it seems impossible not to recognise that the dark grey lines and veinings referred to were produced subsequently to the original formation of the granules. The same phenomena are observable in almost all the ancient oolites also. They may be due to contraction.

Speaking of the granules as a whole, they are very uniform in structure, one granule presenting practically the same character as another, and in this respect they differ markedly from those from other localities presently to be described. They somewhat resemble the pisolite of Carlsbad (Plate III, fig. 9).

Oolitic Granules of Modern Formation from near Black Rock, Great Salt Lake, Utah.

The occurrence of oolitic sand on the shores of the Great Salt Lake has been known for many years, but the structure of the material does not seem to have been dealt with in sufficient detail. It presents many points of interest in the present inquiry, as will be seen.

Mr. I. C. Russell, who collected the material now in my

possession, remarks* that "From the analyses of the tributary streams we know that large quantities of calcium carbonate are contributed to Great Salt Lake in solution; but the chemist fails to find this salt in the brine itself. The extreme scarcity of animal and plant life in the waters shows that it could not be removed by organic agencies †; it must, therefore, either be precipitated, or perhaps in part decomposed and changed to the chloride. The very small percentage of calcium in the lake, however, is sufficient proof that this element must have been precipitated, probably as the carbonate, when the river and lake waters were mingled. The presence of large quantities of oolitic sand along the shores of the lake, which is apparently still in process of formation, is strong evidence in support of this hypothesis." It is a striking fact, as showing the diverse chemical conditions of waters in which oolitic grains are now being formed (no matter whether by chemical or organic agency), that whilst the Pyramid Lake contains less than half of one per cent. of solids in solution, the Great Salt Lake has varied from over 22 to about 13 per cent. during the past twenty years.

The oolitic grains from the Great Salt Lake are very much smaller than those described from Pyramid Lake, the largest of them not surpassing the size of a small pin's head, whilst the bulk are very minute. For the most part they have a shining surface and are spherical, though elongated specimens and compound grains also occur.

In thin sections, under the microscope (Plate III, fig. 3), they are seen to possess a structure totally different to those from Pyramid Lake. Instead of preserving the aspect of extreme regularity, there are very few grains absolutely similar to one another, though the various structures could be grouped and classified. It is not my intention to do this in the present paper. I must now content myself with a general description of them only.

The nuclei are sharply defined, or hazy and merge imperceptibly into the innermost coat. Dealing with the former first we observe that they are frequently formed of angular quartz grains either solitary or aggregated; in every instance the quartz appeared to have been derived, either directly or indirectly, from the destruction of crystalline igneous, or metamorphic rocks. Many of these contain small bubbles and inclusions, and some exhibit the characteristic phenomena due to strain. I mention these facts to show that the quartz has not been deposited from the waters of the lake on evaporation as apparently have some of the nuclei about to be described. Occasionally the nuclei are composed of elongate bodies, evidently of organic origin, spotted with dark patches

* *Op. cit.*, p. 186.

† I do not necessarily endorse this remark: I am merely quoting Mr. Russell's views.—G. F. H.

having a general regularity; these somewhat resemble the nuclei found in the oolitic grains of recent origin from the Bahamas (see p. 67). Speaking in general terms, however, the nuclei of the Great Salt Lake granules fall into our second category, namely, they are hazy and ill-defined. I have devoted considerable attention to the elucidation of the structure of these peculiar nuclei, and although I have not quite satisfied myself as to their precise nature, I beg to make the following suggestion. They are composed of a number of light and dark arms (Plate III, fig. 4), which taken as a whole radiate in branches from a central point, or along a central line as a basis. The dark portions are not definable, but the lighter arms are made of aggregates of extremely minute crystals which from their behaviour in polarised light are undoubtedly crystalline carbonate of lime. Sometimes these radiating crystalline aggregates terminate abruptly against the innermost coat; at others they pass insensibly into it. It is quite easy to see that in all essential particulars they agree with the crystalline matter disposed radially in the concentric coats, where this exists. The suggestion I have to offer then is this: that these peculiar nuclei have crystallised out of the waters of the lake; we know that crystals of salt and other minerals are now forming. The chemistry of the lake teaches us that the first thing disposed of is the carbonate of lime. I do not say whether organic agencies assisted or otherwise in the operation, and we are not concerned with that for the moment. It suffices for the present to suggest that the crystals have been formed out of the mineral matters in solution in the waters of the lake, and were then taken possession of to form the nuclei of oolitic granules. In this connection, notice the similarity to each other of the nuclei shown in Plate III, fig. 3*f–h*.

A structure, by no means uncommon in the granules, consists of a somewhat elongated and dark nucleus, around which thin and beautifully regular concentric coats are displayed, except in respect of half the distance (Plate III, fig. 5). The original nucleus and these layers have then together formed a nucleus around which other concentric coats were formed. At first I was under the impression that this fragmental oolitic nucleus was derived from the destruction of a pre-existing granule. But more extended examination seemed to show that the lower part of the original nucleus was affixed to some object, so that, until it became detached, the concentric coatings could only form round that portion which was free. This view receives some confirmation from the circumstance that the coats are very thin round the apex of the elongated granules, and are much broader and spread out at its base. Since observing this peculiarity, I have noted a similar structure in some Jurassic and Carboniferous oolites. I may say that it has sometimes led to the belief that the granules in certain oolites were derivative.

Amongst many other interesting points connected with the Great Salt Lake granules it may be noted that some, which are almost entirely made of rounded decomposed mineral matter with a thin coat only on the exterior, present considerable analogy with those in certain Jurassic oolites which have been thought to be due to secondary alteration.

The successive coats are not, as a rule, disposed in regular zones, and in general a radial structure obtains. Sharply cut lines running concentrically are conspicuous. Sometimes these are so close together as to suggest tubular structure; but under $\frac{1}{4}$-inch objective they appear to run independently of each other, and I cannot state with certainty that tubules exist in the granules of Black Rock district of the Great Salt Lake.

Oolitic Sand of Modern Formation, Bahamas.

I am indebted to Professor Judd, F.R.S., for the oolitic sand upon which the following observations are based. The occurrence of oolitic granules amongst modern coral reefs is well known. Dana shows* that great quantities of calcareous mud and sand are produced by the breakers which beat upon the outer edge of the reefs. This detritus is partly washed up upon the reefs, where, being cemented by solution and re-deposit, it aids in their consolidation, sometimes acquiring an oolitic structure. Oolitic sand formed amongst coral reefs in the Bahamas has been studied by Sorby,† and others, but many interesting points appear to have hitherto escaped notice.

In shape these very small granules are mostly spherical or ellipsoidal, though some are roughly trigonal, depending in a great measure on the form of the nuclei. The latter are very characteristic, and, so far as the material at my disposal enables me to judge, they are all of the same substance. In thin sections they are light brown in tint, and in some instances are as much involved in the formation of the beautiful dark crosses seen between crossed nicols as are the concentric coats wrapped about them. In ordinary light (Plate III, fig. 6) under a 1-inch objective, the nuclei appear as somewhat indistinct bodies, each possessing a number of more or less rounded portions joined together, the aggregate evidently having been subjected to attrition, as many of these rounded bodies are seen to be cut in two, half having been removed. Regarded under a $\frac{1}{4}$-inch objective, the details of the nuclei present still greater points of interest. The light-brown patches contain a number of small sub-rounded specks both light and dark, and the boundary between the nuclei and their coating is not always well defined. Occasionally vermiform markings appear in the nuclei, and pass over

* Dana, *Corals and Coral Islands*, pp. 152, 194.
† Sorby, *Op. supra cit*, p. 74.

into the enveloping coats, and *vice versa*. At the same time in those granules where the junction of the nucleus with the coating is ill-defined, the precise phenomena are extremely difficult to make out. Another point noticeable in the nuclei is the existence of several irregularly rounded spots of white crystalline matter. They are very minute, and on examination in convergent polarised light the "brush" phenomena were not sufficiently distinct to enable me to ascertain whether the included mineral matter was calcite, or aragonite. It is doubtless one or the other of these. The white mineral is disposed in prisms radiating from an ultra-microscopic particle as a nucleus (if existing) in the centre of each spot. Brilliant colours and a perfectly-formed black cross were obtained on revolving the stage between crossed nicols.

Mr. F. Chapman has suggested to me that the nuclei of these Bahamas granules are the coprolites of fishes, but this is a point upon which I will not venture an opinion at the present moment. They are not unlike the structures sometimes seen adhering to, or forming a part of, nullipores. Coming now to the coatings themselves, it may at once be remarked that, like the nuclei, they differ very materially from those in the granules of Pyramid and Great Salt Lakes. Under $\frac{1}{4}$-inch objective they are seen to be composed of two essential elements. One of these may be described as a number of concentric lineations enveloping the nucleus, the lineations being equidistant from each other during a great part of the journey round. At first I thought these were tubules; a closer investigation, however, showed that this was not the case. I desire to be very emphatic on this point, as I think it is destined to throw much light on the actual nature of the concentric lineations of a number of different kinds of oolitic granules. If we take any one of these light lines and follow it up, we notice (Plate III, fig. 7), that it obtains for very long distances, sometimes more than half-way round the granule; it then disappears either into the dark patches and general haziness presently to be described, or thins out by the coalescence of a light line above with one below. If these light lines were tubules one would not expect them to be so persistent for long distances in practically all the granules where concentric structure obtains. It would be by the merest accident that thin tubes wound round a nucleus in all directions, were cut along their length at all, in the preparation of micro-sections. We might consider them perhaps in a different light if only one were cut here and there, but when the greater part of the coatings consist of these light linear zones, as they very frequently do, it is impossible to recognise them as tubules.

Turning to the other essential element in these coatings it may be described as dark patches consisting of, (1) vermiform markings, sometimes in little colonies; (2) as round spots; and

(3) hazy matter. With reference to the dark vermiform markings (Plate III, fig. 8), they may be said to be practically identical with similar markings seen in the nuclei of many granules as just now alluded to. No one, I think, could have any doubt that these are tubules; they permeate the granules in all directions, and in thin sections are seen to be cut, as they should be, at divers angles. Here is a section apparently of a coiled up tube, there of another wormlike, wriggling portion, farther on is an elongated piece, and then we have transverse sections exhibiting round spots, as placed in our second category above. Let us confine our attention for a moment to the round spots, looking at them with a high-power objective. They occur either singly or in clusters; in some granules they appear to have a preference for certain zones, being checked to some extent by one of the light lineations, in others (less numerous) they are fairly evenly distributed throughout.

A matter to which I desire to call special attention is that these tubules are not mere holes drilled into the granules and then filled with some dark mineral substance; they are veritable tubes possessing a thin, crystalline wall. Thus, each dark spot, where the granule is clearly cut, is encircled by a ring of light which is distinctly doubly-refracting—proving its crystalline nature.

It is now my intention to show that these dark vermiform tubules have been formed independently of the light lineations referred to, and subsequently to them. Let us again take up a clearly-marked concentric lineation and note it well in its course round the granule. We shall observe that here and there the dark tubules intersect it, but they do not in any way cause it to deviate from its course; the dark tubules cut clean through the concentric lineations in every direction, and the latter yet persist, unaffected by the intruders. Even in the hazy portions, and where the tubules are gathered together in great force, a well-marked concentric lineation appears here and there in strict continuity with the unpenetrated portions. No attempt is made to go round or avoid the tubules; the evidence could not be clearer.

There is no radiating structure, properly so called, in any of the granules from the Bahamas in my possession, and I have at least a hundred. But minute, irregular cracks, commencing from the outside and having a general direction towards the nucleus are common. In many instances these cracks extend into the nucleus, and, rarely, they may be seen running through it to the other side of the granule. Here and there they bifurcate, now and then send branches off, which bifurcate in turn, but they are all extremely small, unobtrusive, and practically played no part in the actual formation of the granules. They appear to be cracks due to shrinkage on drying.

To sum up the structure of these granules. They possess a nucleus of a special kind, the nature of the nucleus of every granule is the same, and it may possibly have been organic. In the nuclei are sundry semi-ovate structures which from the circumstance of their being cut off sharply at the nuclear peripheries suggest attrition. Then there are other and vermiform bodies of a tubular character, which are occasionally seen to wriggle out from the concentric coatings and to penetrate the nucleus. The dark tubules cut through the concentric lineations in every direction, the normal course of the latter not being in any way disturbed. This indicates that the vermiform tubules were introduced into the Bahamas granules subsequently to the formation of the latter.

I have other oolites and pisolites of recent formation, having characteristic structures by which they may be readily distinguished from one another, but the foregoing suffices for the present purpose. We will now glance at the structure of some older oolites.

Great Oolite Limestone, Corsham Down Quarry, near Bath.

It will not be necessary to describe in detail the micro-structure of oolitic granules found in the various kinds of Bath stone. They do not appear to have been studied except in a very superficial manner, partly owing, no doubt, to the difficulty of obtaining good sections in such soft stone. I have now a large number showing structure exceedingly well. The particular specimen selected for description (Plate IV, fig. 1) is no better than many others, but is typical of Bath stone as a whole. I obtained it from a stone mine on Corsham Down, about twelve miles east of Bath, in what is known as the "bottom bed" of the building-stone series of the Great Oolite.

In ordinary light the granules are seen to be of a yellowish-brown tint; in shape many are spheroidal, a few ellipsoidal, the remainder being irregular. The nuclei are comparatively large, in some cases forming nearly the whole of the granules. At the junction of them with the coatings, in nearly every granule, there is a narrow zone stained with iron of a deep brown tint. Taking one granule with another, the coatings are very evenly disposed, and many show them in a regular order of succession. After passing beyond the iron-stained zone, is a narrow, fibrous-looking coat of a light tint, similar to the outermost zone, and between these is a broader one, in which the structure, under a 1-inch objective, is not so clear. Well-marked radiating structure is rare, but the concentric zones are beautifully shown. The nucleus in every instance is a fragment of some organism. Here, closely-set tubular markings denote that it belonged to *Terebratula*;

there, the characteristic punctations of the ossicles of a Crinoid, and small portions of the ambulacral area of an Echinoid; in another a section across the cells of a Bryozoan; a small Gastropod, a Foraminifer, a piece of oyster-shell—all have been called into requisition in forming the nuclei of this Corsham Down stone, which is a veritable palæontological museum. We saw nothing like this in the granules from the American lakes, or from the coral reefs of the Bahamas. Not a particle of any mineral from igneous or metamorphic rocks, nothing appertaining to a sandstone or an argillaceous deposit is here observable, and there is no secondary quartz or chalcedony.

Speaking of the nuclei of Bath oolitic granules generally, the absence of any other than remains of a purely organic nature is remarkable, the only exceptions to this being in the Monk's Park district, and in the quarries near Farleigh in the south-east of the area. Even in the last mentioned localities, however, the nuclei not of organic origin are very rare, and consist for the most part of minute fragments of quartz.

On examining the specimen with a $\frac{1}{4}$-inch objective, we observe that, although well-preserved, the structure is not so clear as in the oolitic granules of recent formation. The coatings present close analogy with those of the Bahamas granules, but there are many points of difference. In the Bath oolite the concentric lineations are better marked, they are not so much cut up by the local development of dark patches, they have a tendency to run in zones, and are clearest near the nucleus and in the outermost zone. But, whilst the concentric lineations are so well seen, the darker portions are not as satisfactory. Nevertheless, they present practically the same phenomena as in the West Indian granules. They are not, on the whole, perhaps, so vermiform, neither can one observe the crystalline linings and boundaries to the spots and markings. Arguing by analogy, they may be tubules of the same nature as those found in the recent granules alluded to, though this would not have been suspected unless we had seen them in the fresher material. In other words, oolitic granules from Corsham Down and the Bath area generally, possess remarkably persistent concentric lineations, which are perforated at many points by what are possibly vermiform tubules, though the latter are not so clearly developed as might be, and are not, apparently, present in all the granules. It would not be difficult to dilate at length on this and other peculiarities of Bath oolite, but we are mainly concerned at the present moment with types of structure of oolitic granules in different rocks, for which purpose it is only desirable to lay down general features of intimate structure. Many of the dark spots and patches in these Jurassic granules are doubtless mere mineral stains, whilst others are due to partial decomposition of the rock.

Great Oolite Limestone, Kingsdown, near Box, Wilts.

The sole object of alluding to the limestone from the Longsplatt Quarry, Kingsdown, near Box, is to call attention to the polygonal form assumed by many of the granules (Plate IV, fig. 2). The particular horizon in the quarry is known as the "fine grained" bed. The internal structure of the granules is practically the same as in the Corsham Down stone, and the polygonal form assumed is due entirely to mineral alteration closely connected with the subject of the formation of the matrix binding the granules together. The cause of the polygonal structure it is therefore outside our province to discuss; all we need note is that the outermost concentric lineations present the appearance of being planed off in various directions, and that the original form of the granules has consequently been materially modified. Certain beds of the Inferior Oolite at Painswick Hill in Gloucestershire, and elsewhere, present a somewhat similar appearance.

Portland Stone, Tout Quarry, Isle of Portland.

I have had a large number of oolites from the hard limestone beds of the Portlandian of Dorset cut, but none of their granules are sufficiently well preserved to enable me to satisfactorily decipher their structure. They are much harder than the granules in the Bath stone, or, indeed, of any other normal Jurassic oolite in this country, but they have undergone such alteration that original structures are in every case practically obliterated. It would seem as though they at first became highly decomposed, and that after the work of destruction had been arrested, crystalline conditions set in which has made them harder than they were before.

Judging from what structure remains (Plate IV, fig. 3) the grains of this Portlandian oolite contain enormous nuclei, with but a thin film of coating exteriorly, though there are exceptions to this rule. They differ widely from the granules in the Bath stone in being much smaller, in possessing a semblance of radiating structure, whilst the granules frequently interpenetrate each other. It seems clear that if fresher material could be obtained the intimate structure would be proved to be distinctive. I am not able, therefore, to add anything to the remarks of previous observers. At the same time I may call attention to the fact that the type of granule above described is peculiar to the Portlandian as a horizon. I have examined sixty slides of Portlandian oolite from the Isle of Portland, eight from the beds of same age in the Isle of Purbeck, nine from those in the Vale of Wardour, and five from the Hartwell and Brill area in Bucks, and they all (save one next to be described) present granules identical in character with

one another, in precisely the same way as the type of Bath stone described obtains over the Bath area from Dundry to Corsham, and Bradford to Colerne.

PORTLAND STONE, TEFFONT QUARRY, NEAR TISBURY, WILTS.

The specimens on which the following observations are based came from what is known as the "brown bed," near the summit of the Portlandian series, in the Chilmark "ravine," at a working locally called Teffont Quarry. This quarry must not be confounded with that near Teffont Evias Church.

I have said that, with one exception, the numerous slides of Portlandian oolite in my possession show hardly any traces of structure. This (Plate IV, fig. 4) is the exception alluded to, and I believe that this is merely the same kind of oolitic granule in a fresher condition. The nuclei, as in the others, are as a rule abnormally large. They consist for the most part of fragments of various organisms; but here and there angular quartz sand grains appear, about which the coatings are closely wrapped, or the nucleus may consist of two or more quartz grains accompanied by semi-opaque mineral matter, probably kaolin, derived from the decomposition of felspar. The coatings are distinguishable from all others yet described in possessing a ringlet, or white zone, between the outermost layers and those next the nucleus. Very rarely there are two such white zones, the second one being added to the outside. The dark layers alluded to, dull brown in tint, consist of a number of concentric lineations. Between crossed nicols a distinct radiating structure is observed, the closely-set acicular prisms of which polarise in brilliant colours. In the darker zones, which are sharply defined by the concentric lineations, the prisms are seen to be stained by a brown pigment, and a point to which I desire to call special attention is that at more or less regular intervals (there seems to be a method in their occurrence) several contiguous prisms are stained almost to opaqueness. The result is that the brown zones present the appearance of alternations of bundles of transparent with semi-opaque prisms. It is noteworthy that in almost all the granules the dark bundles, after being stopped by the concentric lineations dividing the white zone from the brown, appear again in the same relative positions in the next brown zone above, thus missing, as it were, the white zone. Rarely, probably not in one granule per cent., the dark bundles obtain from the nucleus to the circumference, but they are always fainter in the light zones.

I will not pretend to account for the staining of the dark prisms at more or less regular intervals in these Portlandian granules; but I may say that a very superficial examination of the material from Great Salt Lake shows that precisely the same thing occurs in the granules now being formed, and that the

phenomenon is closely connected with the genesis of the acicular prismatic crystals alluded to.

I have not detected in this oolite, in any one of the granules, any semblance of vermiform tubules; the material is well-preserved—almost as well as that of recent formation—the few dark spots occurring are obviously due to local decomposition.

Lincolnshire Limestone, Weldon, Northamptonshire.

The oolites of the Lincolnshire Limestone series possess a remarkable structure easily distinguished from that of any other stone. I have examined them at many points—Weldon, Ketton, Stamford, Ancaster, Barnack, etc.—and although in minute particulars the structure of the stone differs in each locality, yet there is a sort of generic resemblance between them all, which may be typified by that from the Weldon quarries, near Kettering, where the material is very fresh—as though it were of modern formation. The particulars that follow more especially refer to what is known as the "A1 bed" in the quarries.

The granules (Plate IV, fig. 5) are small, generally ellipsoidal, or spheroidal, a few are roughly trigonal. The nuclei consist of fragments of various kinds, practically all organic, as far as can be ascertained. Of the thousands of granules that have passed under my eye, I have only seen one with a nucleus not of an organic nature, and that was an angular quartzose sand grain. The nuclei appear to have undergone the same mineral changes as have the granules of the Portlandian of Dorset, just described. Foraminifera and shell fragments are common, small gastropods, too, are sometimes completely enveloped, whilst occasionally the ossicle of a Crinoid, better preserved than the rest, makes its appearance. But the most characteristic feature of the granules, which serves to distinguish them from all others of my acquaintance, is the coating. This for the most part is thin, sometimes reduced to a mere film when the nucleus is very large, but it is of a brilliant yellow colour, each dull nucleus being, as it were, set in a circlet of gold. The coatings themselves, seen under a 1-inch objective, do not present zonal structure, or only very faintly so. The concentric lineations are fairly equidistant from one another.

Under $\frac{1}{4}$-inch objective the detail becomes exceedingly clear. The coatings have a fanciful resemblance to a number of hoops of practically the same width arranged one within the other with occasional closely-set lines running round with them. Each of these hoops is made up of a number of extremely minute prisms of calcite or aragonite, of a fibrous aspect, converging upon the nucleus, which polarises in feeble tints. The whole is dotted over with grey and brown spots, the latter being specially abundant in the outer portion of the coatings.

Dealing first with the grey spots, it is tolerably clear that some are due to decomposition ; others are of the same nature as those described in the granules of the Portlandian from Teffont Quarry and from the Great Salt Lake, namely, they belong to a series of semi-opaque bundles at more or less regular intervals radiating from the nucleus, but interrupted here and there by the concentric zones. I can see nothing in the nature of tubules in any of these Weldon granules.

Turning to the brown spots alluded to, they are small, and of the same character as large masses occasionally seen in the matrix. They are transparent in very thin sections, and present all the usual attributes of iron. From the manner in which they occur it is certain that they have been introduced into the granules subsequent to the formation of the latter. They are most abundant in the bright yellow zone round the exterior of the granules, though they are often seen also in the nuclei, where they sometimes fill up the small punctations of brachiopod and other shells.

Interpenetration is well exemplified by the Weldon granules (Plate IV, fig. 5). They are seen not only to interpenetrate each other, but to adhere to fragments of various kinds found in the rock. A glance at our illustration explains this clearly, and it is noteworthy that neither when the granules join each other, nor when they adhere to foreign bodies do the concentric coats deviate, or attempt to avoid the body entering them. There are no chips nor pieces showing how this came about, and one is constrained to remark, that whatever hypothesis is made to account for the origin of the granules, will have to account also for these phenomena. Almost every granule interpenetrates or is interpenetrated, and sometimes one granule exhibits the two phenomena, in fact the strength of the stone is largely dependent on this. I have observed a similar structure in other oolites.

GREAT OOLITE, MINCHINHAMPTON COMMON, NEAR STROUD, GLOUCESTERSHIRE.

Although I have visited Painswick, Birdlip, Leckhampton, and other places in the vicinity, and have had a number of sections cut from specimens collected, I cannot claim to possess any special knowledge of the Cotswolds. With such an excellent investigator in the field as Mr. E. D. Wethered, who has practically made that district his own, and has written much upon the structure of the oolites in it, it is doubtful whether I should be able to add much to our knowledge concerning them. But I cannot help calling attention to a remarkable oolite (Plate IV, fig. 6) on Minchinhampton Common, near Stroud. I must not describe the rock, only the granules in it. They are very small indeed, smaller than in any other Jurassic oolite that I know of.

Except that they are oolitic granules, however, there is not much to be said. Their structure is entirely obliterated, only the nuclei with a dark, opaque covering remain. But, in the field, one observes that this fine-grained stone has bands of coarser oolite running through it. A remarkable fact, however, is that whilst the minute granules remain, the coarser ones have practically disappeared, a number of holes being left to denote their former presence, and occasionally they left their outermost coats behind them also. From the fragments that remain it would appear that there is a general resemblance between them and the typical Bath oolite granules; smaller ones of the same type can be seen in two or three localities in the Bath area.

CARBONIFEROUS OOLITE, SOMERSETSHIRE.

The fact of the Carboniferous Limestone being oolitic in the neighbourhood of Bristol is well known, though the actual details yet require investigation, except in so far as the gorge of the Avon is concerned.* I have not gone very thoroughly over the area, but a short account of the structure as it occurs at Vobster, near Frome, in the famous Cheddar Pass, at the Hollies Lane quarry, Walton, near Clevedon, and near Clifton Bridge, Bristol, may not be uninteresting. As might naturally be supposed, the granules have in every case become much modified by the processes involved in rendering the limestones crystalline; occasionally they are almost obliterated.

Vobster Quarry, Mells, near Frome.—The granules in this rock (Plate IV, fig. 7) are semi-opaque and exceedingly small. The alteration has proceeded to such an extent as to render the majority of the granules, including their nuclei, perfectly useless so far as arriving at details of structure is concerned. A few that are better preserved than the rest have rather large nuclei, composed of shell fragments, with a thin coating possessing a few concentric lineations, but the whole are too obscure to yield satisfactory results.

Cheddar Pass.—Containing a large proportion of very small granules like the preceding, which are equally obscure. But, in addition, there are some larger granules having a foraminifer, some other organic fragment, or semi-opaque nuclei, around which is a thin coating composed of radiating acicular prisms, forming a characteristic light zone. Here and there, bundles of prisms are darker, and these alternate with bundles of light ones. Speaking generally there are comparatively few concentric lineations, and but little tendency to dark zoning.

Clifton, Bristol.—The granules are better preserved in this (Plate IV, fig. 8) than in any other Carboniferous Limestone I

* See Wethered, *Quart. Journ. Geo. Soc.*, vol. xlvi (1890), p. 271.

collected in the area. The structure is peculiar to the rock. The granules are much larger than at Vobster, or Cheddar, though a few like those at the former locality appear. The prevalent type has a small nucleus surrounded by two or three successive dark zones, separated from each other by darker concentric lineations. In striking contrast with these, and next to them, is a zone composed of many very regular equidistant concentric lineations, bounded outwardly by a sharp, dark one. The outermost zone is the lightest of all; it possesses but few concentric lineations, though the order of occurrence is variable. The nuclei are frequently cracked across, and the mutilation sometimes extends into the innermost concentric zones, but rarely to the circumference; the granules have been subjected to enormous strain, some being faulted. Radiating structure is well shown, dark bands alternating with lighter ones. Decomposition has led to the formation of small black patches, and it seems to have been directed in its operation by the dark bundles of radiating prisms.

The most remarkable type of granules in this limestone, however, yet remains to be described. In these there is no trace of a nucleus, not because the granule has in the preparation of the section been cut above or below the spot where one might have been (as I have ascertained by direct experiment); only a thin line is seen, on which a number of crystals are built up and from which they radiate irregularly to the circumference. Their arrangement is such as to present a kind of spongy appearance. These troubled me for a long time, and I at first thought they were the ordinary granules irregularly decomposed along lines directed by the radiating prisms, for the structure is not very sharply defined. I had occasionally observed such granules in slides of Jurassic oolites. This idea had to be abandoned, however, on examining the clearer material from Great Salt Lake, in which many granules of somewhat similar kind occur, and the freshness of which precluded the possibility of their being decomposed. At the same time, I can show a complete transition from the normal type of granule to that now under discussion, in the Clifton Carboniferous Limestone. Indeed, there are granules half of which are of the one type and half the other.

Other kinds of granules in the Carboniferous Limestone of the same area present many points of interest, which I regret that I cannot describe at present. Their general facies is like that of Clifton, and both present a close analogy with the recent material from Great Salt Lake.

Hollies' Lane Quarry, near Clevedon.—So far as can be ascertained from this rock, in which the granules are so much decomposed as to be almost obliterated, the structure is essentially the same as that from Clifton.

DEVONIAN OOLITE, NEAR ILFRACOMBE.

This material has been so clearly described by Mr. F. Chapman* that all I need do is to record the fact that the granules differ in structure from any of the oolites previously mentioned. The nucleus in some instances consists of a quartzose sand grain, and both concentric and radiating structure are well shown. The granules are remarkable as exhibiting a large number of concentric lineations, amongst other things.

SILURIAN OOLITE, TRENTON SERIES, CENTRAL COUNTY, PENNSYLVANIA.

I do not know the precise locality of this peculiar rock, and I only introduce it here as being an excellent example of an oolite that has been completely silicified (Plate IV, fig. 9). Its original structure has for the most part disappeared, what remains show that the nuclei consist of quartzose sand grains, or organic fragments surrounded by a number of unbroken concentric zones or bands of approximately equal thickness. Under the polariscope a finely granular radiating structure is apparent. A characteristic feature is the perfectly spheroidal shape of nearly all the granules.

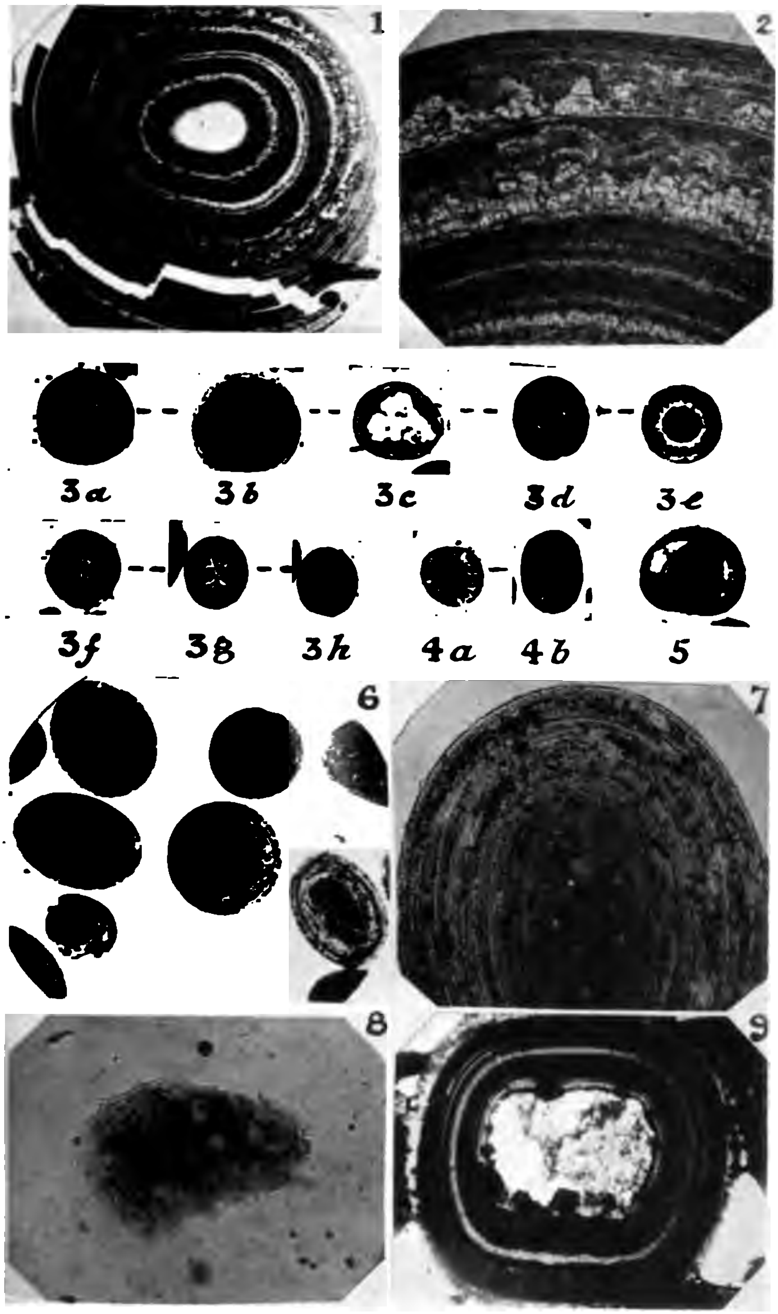
ORDOVICIAN OOLITE, HIRNANT, NORTH WALES.

The circumstance that limestone bands of the Bala series are oolitic in the valley of the Hirnant has been made known by Mr. L. W. Fulcher, who described † the main features of their structure a short time since, and I have not much to add to his remarks. A slide in my possession shows that coats near the exterior of many granules have been removed, possibly by decomposition, and at one time they were loose in the holes thus produced. A similar phenomenon may be observed in the Bath oolite, especially in that from Coombe Down and district. The nuclei are in almost all cases organic fragments, occasionally a U-shaped piece seems to occur (Plate IV, fig. 10), where, through the section being cut across the top of the two arms, the elongated granule is made to appear as though it had two nuclei. Concentric lineations are especially well shown.

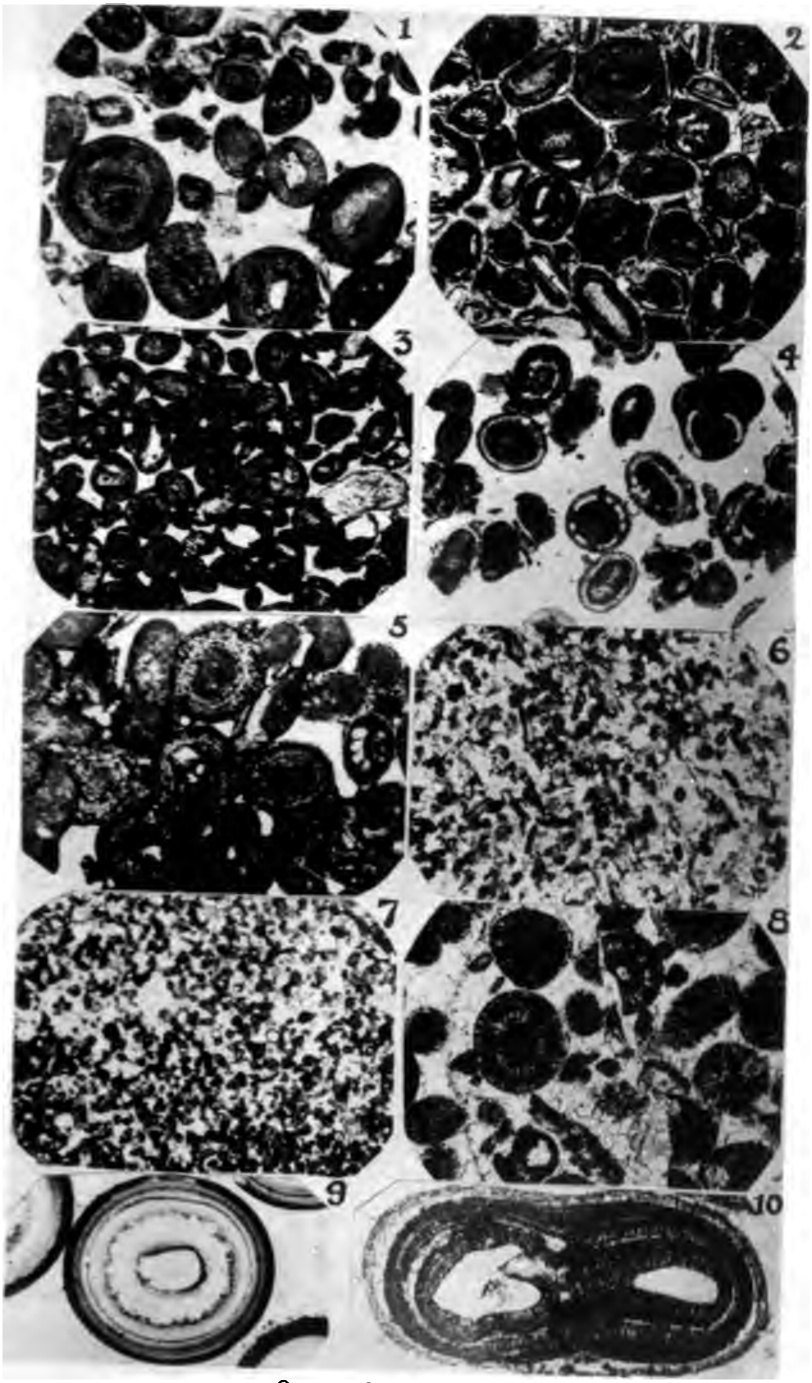
CONCLUSION.

A consideration of the foregoing shows that many types of oolitic granules exist; that there is considerable difference in structure in them as traced from one geological formation to another; that certain types are confined to certain horizons, at least locally (over many square miles) if not generally; that the greatest divergence in structure exists between those formed respectively in salt water and in the water of hot or warm springs;

* F. Chapman, *Geol. Mag.*, n.s. dec. iii, vol. x (1893), p. 100.
† L. W. Fulcher, *Geol. Mag.*, n.s. dec. iii, vol. ix (1892), p. 114.



Pisolitic and Oolitic Granules.
(Modern.)



OOLITIC GRANULES.

(JURASSIC, CARBONIFEROUS, SILURIAN AND ORDOVICIAN.)

that those formed in the vicinity of coral reefs (as exemplified by one instance, however) may probably be distinguished from either, but are more like those from salt water; and that certain oolitic granules possess vermiform tubules which appear to have been introduced into them subsequently to the original formation of the granules. These observations do not necessarily refer to pisolites; I have not yet had an opportunity of examining enough of these to express an opinion with reference to their structure. Neither do I profess to have described all the types of structure found in each sand or rock alluded to; a great deal remains to be done in that direction and in the minute examination of oolitic structure generally.

Finally, I have to record my sincere obligations to Mr. A. Edouard Lardeur, F.G.S., and Mr. Percy Emary for taking the micro-photographs and making the lantern slides by which the paper is illustrated at this meeting; also to Mr. F. Chapman, who so skilfully prepared nearly all the micro-slides on which the foregoing observations are largely based.

EXPLANATION OF PLATE III.

MICRO-PHOTOGRAPHS OF OOLITIC GRANULES.

FIG. 1.—From the beach of "The Needles," Pyramid Lake, Nevada (× 60), p. 63.
FIG. 2.—The same, showing more detail (× 240), p. 63.
FIG. 3*a*—*h*.—From near Black Rock, Great Salt Lake, Utah (× 60), p. 65. Notice similarity of nuclei in 3*f*, *g*, and *h*.
FIG. 4*a*—*b*.—The same locality, showing granules almost entirely composed of irregular, radiating, prismatic crystals (× 60), p. 66.
FIG. 5.—The same locality; details of a peculiar granule (× 60), p. 66.
FIG. 6.—From modern beach, Bahamas (× 60), p. 67.
FIG. 7.—The same locality; giving details of concentric lineations perforated by dark vermiform tubules (× 240), p. 68.
FIG. 8.—The same locality; a group of tubules (× 240), p. 69.
FIG. 9.—Pisolite spherule, from Carlsbad (× 60), p. 64.

EXPLANATION OF PLATE IV.

MICRO-PHOTOGRAPHS OF OOLITIC GRANULES (ALL × 60).

FIG. 1.—From the Great Oolite of Corsham Down Quarry, Corsham, Wilts, p. 70.
FIG. 2.—From the Great Oolite of Longsplatt Quarry, Kingsdown, near Box, Wilts, p. 72.
FIG. 3.—From the Portland stone of Tout Quarry (*Whit-bed*) Isle of Portland, p. 72.
FIG. 4.—From the Portlandian of Teffont Quarry, Chilmark "Ravine," near Tisbury, Wilts, p. 73.
FIG. 5.—From the Lincolnshire Limestone of Weldon Quarries (*A*1-*bed*), near Kettering, showing interpenetration, p. 74.
FIG. 6.—From the Great Oolite of quarry on Minchinhampton Common, near Stroud, Glos., p. 75.
FIG. 7.—From the Carboniferous Limestone of Vobster Quarries, near Frome, Somerset, p. 76.
FIG. 8.—From the Carboniferous Limestone, near Clifton Bridge, Bristol, p. 76.
FIG. 9.—From the Trenton Series of Central County, Pennsylvania, p. 78.
FIG. 10.—From the Ordovician Limestone of Hirnant, N. Wales, p. 78.

THE GEOLOGICAL HISTORY OF THE HIMALAYAS.

(WITH A SKETCH MAP.)

By LIEUTENANT-GENERAL C. A. McMAHON, V.P.G.S.

[Being the Presidential Address delivered 1st February, 1895.]

THE Himalayas are "generally supposed," to use the words of Mr. Medlicott, late Director of the Geological Survey of India, "to have been upraised in late Tertiary times";* and Sir Henry Howorth has pushed this popular conception to its extreme limits by asserting that "the great mountain masses of eastern Asia" were probably upheaved "as late as the time when the mammoth age came to an end";† that is to say, long after the appearance of man in Britain, for the mammoth lived well into the human period.

The last-named author tells us in a subsequent paper that this upheaval was "very rapid, if not sudden."‡ If evening papers, and startling posters, had existed in those days, the sudden rise of the Hima-álaya (abode of snow), like Venus from the depths of the sea, must have supplied interesting pabulum for sensational writing.

As so much misapprehension on the subject of the geological history of the Himalayas seems still to linger in some minds, it may be worth while to devote a little time this evening to try to arrive at some clear ideas on the subject.

As the mountain ranges that constitute the Himalayas are composed of rocks of all ages from Tertiary to pre-Cambrian, we should obtain a very inadequate idea of the history of the Himalayas were we to exclude from our view all events that preceded the last set of earth-movements that set in during the Tertiary period. This would be very much like beginning the history of England with the reign of George the First.

The able geologists to whom we are indebted for the *Manual of the Geology of India* frankly recognised that the Himalayas had a pre-Tertiary history. Thus, Mr. Medlicott tells us "that the Himalayan mountain area was defined before the deposition of the Sabathu nummulitic rocks"§—that is, in pre-Tertiary times; and in another place he wrote: "In early and middle Secondary times a general elevation occurred of the south Himalayan area along the border of which the Sirmur deposits subsequently took place."||

Dr. Blanford, the other joint author of the first edition of the *Manual*, in his lucid introduction to that work, expresses the

* Medlicott, *Manual G.I.*, 1st edn. (1879), p. 520.
† Howorth, *Geol. Mag.* (1891), p. 163.
‡ *Ib.*, *Geol. Mag.* (1894), p. 405.
§ *Memoirs, G.S.I.* III. 174 (1865.)
|| *Records, G.S.* IX (1876), p. 51.


PANJAB
RAJPUTANA
SIWALIK RANGE
GARHWAL
HIMALAYA
HUNDES
DERA GHAZI KHAN
MULTAN
DERA ISMAIL KHAN
LAHORE
KOHAT
Indus R.
Sutlej R.
Ravi R.
Jumna R.
Ganges R.
GREAT TIBET
KUEN LUN

opinion that "the Himalayan area was probably in great part land at a much earlier period,"* than that which witnessed the deposition of the Eocene strata.

Mr. Oldham, in his interesting chapter on the origin of the Himalayas, in the second edition of the *Manual*, writes: "The elevation of the Himalayas commenced with the Tertiary era; and the range only attained an elevation comparable to which it now possesses towards the commencement of the Pliocene period."†

Here the word "elevation" is used in a highly technical sense. "In speaking of the elevation of the Himalayas," the author explains some pages further on, "only that final compression is meant, which caused it to rise as a conspicuous mountain range with the same limits and extent as at present, and the antecedents which may or may not have been the direct cause of this result are excluded."‡

It is this technical mode of speaking of the last phase in the history of the Himalayas, as if it were the only event worthy of notice, adopted by some writers — beginning the History of England with the reign of George the First—that is, I think, mainly responsible for the misapprehensions that have arisen regarding its origin.

"The general conclusion we may arrive at," wrote Mr. Oldham in 1888, "is that throughout the whole of the Palæozoic and Mesozoic periods the area under consideration [the Simla region] has been alternately land and sea."§

Our fair Venus, Hima-álaya, has then a history; and I propose to consider briefly this evening whether we can learn any interesting facts regarding her infancy and youth.

Among the rocks of which the Himalayas are built up some are undoubtedly as old as Cambrian, and probably the crystalline schists are of pre-Cambrian age.

We have gneissic rocks in abundance intercalated not only with the schists but with rocks of various ages. Some of these gneissic sheets and masses, which at the date of the publication of the first edition of the *Manual* (1879), were regarded as metamorphosed sedimentary rocks, have since been proved to be of igneous origin; ‖ and it is highly probable that when outcrops in other localities are closely studied, their intrusive character will be established.

Not many years ago geologists generally supposed that a foliated structure in a crystalline rock conclusively proved its sedimentary and metamorphic origin; and this prepossession closed their eyes so completely that the plainest evidence of the

* *Manual G. I.*, 1st edn. (1879), p. lvi.
† *Ib.*, 2nd edn. (1893), p. 479.
‡ *Ib.*, 2nd edn. (1893), p. 48?.
§ *Records G. S. I.*, xxi, 143 (1888).
‖ McMahon, *Records, G. S. I.*, xvi, 129 (1883), xvii, 53, 168 (1884).

igneous character of a rock failed to obtain admission into their minds. Thus one of our ablest Indian geologists in describing the Hazara "gneiss" actually tells us that he "found what appeared to be distinct dykes and veins [of gneiss] among the schistose rocks"; and that he even found "masses of the adjoining schists included in the crystalline gneiss"; and yet in the face of such evidence of igneous origin, he finally arrived at the illogical conclusion that "an extensive series of mechanically-formed rocks had undergone tranformation into gneiss."*

The dominance of old and exploded ideas have not yet, I am sorry to say, completely ceased, and there are still some who think that foliation *plus* interbedding is sufficient evidence of a metamorphic, in contradistinction to an igneous origin, forgetting that a partially-consolidated sheet of granite intruded under great pressure into already metamorphosed, or partially metamorphosed beds, would naturally present the appearance of a regular member of a normal sequence.

Much work in the field, combined with the skilled study of thin sections under the microscope, is still needed to elucidate the age and history of many of the crystalline rocks of the Himalayas.

The occurrence of a crystalline schist series in the Himalayas extensively invaded by dykes, sheets, and veins of granite, has been noted by myself and others. A similar series of schists in the Central Himalayas has been described by Mr. Griesbach† and named the Vaikrita system. We are told that Vaikrita is the Sanscrit for metamorphosed; and as this would seem to imply a knowledge of rock metamorphism by our Aryan brethren, it is to be regretted that their views on the vexed question of the origin of the crystalline schists have not been handed down to us.

Between the crystalline schists and the rocks of Silurian age an "enormous thickness" of beds occur which Mr. Griesbach‡ calls the Haimanta system. This includes a "great thickness" of "coarse conglomerate, or boulder bed," and slates abounding in ripple-marks.

The abundance of these marks and the great thickness of the "boulder bed," shows plainly enough that when the Haimantas were laid down to a thickness of 3,000 or 4,000 feet,§ high land must have existed in the immediate neighbourhood; and as the rolled and "sub-angular fragments contained in the conglomerate consists of quartz and *gneiss*," ‖ one may, I think, fairly infer that the high land which was then suffering erosion consisted of crystalline rocks.

* *Records, G. S.* xii (1879), pp. 118-119.
† *Memoirs, G.S.I.*, xxiii (1891), p. 41.
‡ *Ib.*, 49, 224.
§ Greisbach, *Memoirs G.S.I.*, xxiii (1891), p. 55.
‖ *Manual G.I.*, 2nd ed. (1893), p 114.

Mr. Griesbach considers the Haimanta system (in part Cambrian, in part older) to have been a "littoral formation," and believes that "one of the earliest Himalayan disturbances occurred immediately before Haimanta times." *

Why are uniformitarian geologists, I may ask in passing, so fond of the word "disturbance"—a word redolent of the Meteorological Reporter's Office, and painfully suggestive of sudden cataclysmic storms?

Judging from the outcrops of crystalline schists now to be seen, this old ridge of Vaikrita rocks must have approximately occupied very much the same position as the existing line of the Himalayan snowy peaks. Even as far back as Cambrian times, therefore, the direction of the Himalayan axis seems to have been determined, and this direction was substantially what it is to-day. How inadequate, therefore, is the conception of those who suppose that the Himalayas came into existence at the close of the Eocene epoch.

The view above expressed is substantially the one held by Mr. Medlicott in the first edition of the *Manual of the Geology of India*,† and is the one adopted by Mr. Griesbach in his *Memoir*.‡

In the Salt Range, volcanic lavas and ashes have been observed§ which must be referred to the Cambrian period, and in the Himalayas General Strachey has noted the occurrence of extensive outcrops of what appeared to be contemporary basaltic "greenstone," and ash, in rocks of this age.‖ Stoliczka also describes "greenstone" "in regular beds between the other rocks," which he believed to be "coeval." They occur all through his Bhabeh series (now believed to be in part Silurian, but mainly of Cambrian age¶), and share in all the contortions of these rocks.**

It would therefore appear that in the Cambrian period volcanoes were active in the Himalayan area.

During Silurian times the sea covered that part of the N.W. Panjab along which the Indus now flows, and also a portion of the Central Himalayas,†† a fact proved by the coral limestone of Hundés and Spiti,‡‡ and other fossil evidence.

The elevated chain of crystalline rocks, above alluded to, appears to have continued from the Cambrian into Silurian times without very material change; and a land connection between

* Griesbach, *Memoirs G.S.I.*, xxiii (1891), p. 225.
† *Manual G.I.*, 1st ed. (1879), p. 679.
‡ *Memoirs G.S.*, xxiii (1891), p. 225.
§ Wynne, *Memoirs G.S.*, xiv (1878), p. 75.
‖ Strachey, *Q.J.G.S.*, vii (1851), p. 300.
¶ Griesbach, *Memoirs G.S.*, xxiii (1891), p. 50.
** Stoliczka, *Memoirs G.S.*, v (1866), p. 20.
†† Oldham, *Manual G.I.*, 2nd ed. (1893), p. 492.
‡‡ Strachey, *Q.J.G.S.*, vii (1851), p. 304; Griesbach, *Memoirs G.S.*, xxiii (1891), p. 56; Oldham, *Manual G.I.*, 2nd ed. (1893), p. 114.

this mountain area and Peninsular India appears to have existed in those early days.*

The evidence to prove the continuance of this primitive Himalayan chain during the Silurian period appears to be strong. Mr. Wynne tells us of ripple-marked slates in the Karána Hills and other indications of the proximity of land, near the Salt Range, in the direction of Peninsular India;† Mr. Lydekker notes the occurrence of ripple-marked beds in the slates of his Panjál series; ‡ and I exhibit this evening a ripple-marked slab which I found in the Simla slates near Simla. The great slate series, to which the above outcrops are to be referred, is marked Cambro-Silurian on the map which accompanies the second edition of the *Manual of the Geology of India*; and this ripple-marking seems good evidence of the proximity of land when these marine § slates were laid down.

This great slate series occurs on both flanks of the primitive crystalline rocks, and the two outcrops unite in the N.W. of Kashmir to sweep down towards Attock along what seems to have been a fiord, or sea, filling an ancient valley of erosion between elevated ridges of old crystalline rocks. There seems no reason to suppose that the slate series was ever continuous across these crystalline ridges.||

In those early days the N.W. shores of Peninsular India appear to have run near the Salt Range in a north easterly direction until it merged into the elevated mountain region of the N.W. Himalayas. One arm of this land extended through Leh and Scardo, and curved round in a south-westerly direction into Afghanistan; whilst another shorter and more southerly arm extended through Chini, and the neighbourhood of Deotiba, into Kashmir, where it was cut off from the Leh-Scardo arm by the Silurian fiord sweeping round from its north-eastern flank to join the Srinagar-Attock fiord.

Vulcan appears to have been very active in the Himalayan area during the Silurian period.¶ The beds of volcanic ash described by Mr. Middlemiss, in Western Garhwál,** which Mr. Oldham tells us belong to this period,†† are said to be some miles in thickness.

In the Salt Range, and in Hazára, a break occurs between the Silurian and the Carboniferous series‡‡ accompanied by elevation

* Oldham, *Manual* (1893), 492.

† Wynne, *Q.J.G.S.*, xxxiv (1878), p. 355.

‡ Lydekker, *Memoirs G.S.I.*, xxii (1883), p. 263.

§ Wynne, *Q.J.G S.*, xxxiv (1878), p. 355; Blanford, *Manual G.I.*, 1st ed. (1879), p. xxvi.

|| Medlicott, *Manual G.I.*, 1st ed., 630.

¶ Stoliczka, *Memoirs G.S.*, v (1866), p. 20; Wynne, *Memoirs G.S.* xiv (1878), pp 75, 161; Blanford, *Manual G.I.* (1879), p. xxvi; Lydekker, *Records G.S.I.*, xiv (1881), p. 29.

** *Records G.S.I.*, xviii (1885), p. 74; xx (1887), p. 34.

†† Oldham, *Manual G.I.* (1893), p. 117.

‡‡ Wynne, *Records G.S.I.*, xv (1882), p. 164; *Manual G.I.*, 2nd ed. (1893), pp. 109, 129.

and denudation ;* but in the Central Himalayas perfect uniformity exists between them.† No Devonian rocks are known in the Salt Range or in the Upper Panjáb,‡ but Mr. Griesbach believes that the dark blue limestones (700 or 800 feet thick in the Central Himalayas) which extends from Nepal to Spiti, and into Kashmir,§ are of Devonian age. Devonian fossils were found in eastern Tibet by the Abbé Des Mazures.|| These facts appear to indicate that at the close of the Silurian period a rise in the north-west coast line of Peninsular India took place; whilst at the same time a deepening of the sea, which we have seen swept round from the north-east of the Chini-Deotiba crystalline ridge into Kashmir, set in. During this period, and doubtless in connection with the same set of earth-movements, the link between the Himalayan mountain area and Peninsular India appears to have been severed; for littoral deposits of Carboniferous age¶ "are found all along the Himalayan ranges from Kashmir to the frontier of Nepal."**

These changes were probably connected with volcanic activity in parts of the Himalayan area. "Very considerable outflows" of trap took place in the Silurian period in Kashmir, and "continued to take place during a part, or the whole, of the Carboniferous period."†† Considerable thicknesses of basic volcanic rocks in different parts of the Himalayas belonging to this period have been described by Mr. Lydekker in Kashmir,‡‡ and by myself in the Dalhousie, Satlej, and lower Ravi areas.§§ Those near Dalhousie described by me come in between the carbonaceous infra-Krol series and a conglomerate which I correlated with the Blaini conglomerate of the Simla region.|||| Contemporaneous volcanic rocks occur in a similar position in Kashmir.¶¶ Mr. Oldham appears to consider that the Blaini conglomerate, which was previously supposed to be of Silurian age, is, like the Talchir conglomerate, of Upper Carboniferous age, or somewhat newer.*** If this be so, then the volcanic rocks must also belong to the Carboniferous period. This conclusion I had already arrived at for the volcanic series at Rámpur in the Satlej valley.†††

* Wynne, *Q.J.G.S.* (1878), p. 356.
† See references at ‡‡ p. 85.
‡ Wynne, *Q.J.G.S.*, l.c.
§ Griesbach, *Memoirs G.S I.*, xxiii (1891), p. 214.
|| Oldham, *Manual G.I.*, 2nd ed. (1893), 118.
¶ I refer more particularly to Mr. Medlicott's black, carbonaceous, infra-Krol series. This must be the representative of the Gondwána (Upper Carboniferous) of Peninsular India.
** Griesbach, *Records G.S.I.*, xix (1885), p. 266.
†† Lydekker, *Records G.S.*, xiv (1881), p. 29.
‡‡ Lydekker, *Memoirs G.S.*, xxii (1883), p. 217.
§§ McMahon, *Records G.S.*, xv (1882), pp. 34, 155; xvi (1883), p. 36; xvii (1884), p. 34; xviii (1885), p. 82; xix (1886), p. 67.
|||| McMahon, *Records*, xiv (1881), p. 306; xv (1882), p. 34; xvii, p. 34; *Manual G.I.* (1893), p. 137.
¶¶ *Manual G.I.*, 2nd ed. (1893), p. 135.
*** Oldham, *Manual* (1893). Compare p. 137 with pp. 129, 133, 135, 206.
††† *Records G.S.*, xix (1886), pp. 81, 82, 85.

Mr. Oldham remarks in the second edition of the *Manual* that "the great Gondwána era [Upper Carboniferous] opened with a period of exceptional cold. The Peninsula was a land area over which many large lakes were probably scattered, while on land there were glaciers flowing down into these lakes, and into the sea which covered part of the great Indian desert, the north-west Panjab, and a large portion, if not the whole, of the area occupied by the Himalayas west of the Ganges valley."*

That the sea at that period did not cover the whole of the Himalayan area is clear to my own mind. Mr. Oldham himself describes arkose beds which apparently belong to this age; † whilst Mr. Lydekker found ‡ granite pebbles in the conglomerate of his Panjál system, the conglomeratic part of which is considered by Mr. Oldham to be of upper Palæozoic age, and to be the equivalent of the Blaini conglomerate which is referred to the upper Carboniferous period.§ That these granite boulders "were derived from an ancient land area composed of a rock very similar to the porphyritic granite of the Dháola Dhar" is admitted by Mr. Oldham himself.||

I also found a boulder of granitoid gneiss in the conglomerate of the Chamba area, which I correlated with the Blaini conglomerate of the Simla area.¶ This specimen resembles the Himalayan gneissose granite, and it is not like the granitoid rocks of the neighbouring parts of Peninsular India. A peninsular source has never been suggested for any of the boulders in the conglomerates of the Simla, Dalhousie, or Kashmir areas, and I see no escape from the conclusion that elevated land formed of crystalline rocks existed in the Himalayan area when these conglomerates were laid down.

Mr. Griesbach in his *Memoir on the Central Himalayas*, after noting the great physical changes that took place at the close of the Carboniferous period in the Himalayas, Afghanistan, and Persia, remarks: "Evidently the changes which took place near the close of the Carboniferous period, were of a very widespread nature; and if it required proof that the great wrinkling process, which resulted in the elevation of the Himalayas, did not begin in young Tertiary times, but rather was continued up to that time, and even prolonged after it, the 'break' after upper Carboniferous times, must needs be strong evidence that even in Palæozoic times, at least, the main outlines of the Himalayas must have been foreshadowed, and that even then the ancient coast-line could not have been very far removed from the present limits of the Indian Himalayas."**

* Oldham, *Manual G.I.*, 2nd ed. (1893), p. 493.
† Oldham, *Records G.S.*, xx (1893), p. 161.
‡ Lydekker, *Records G.S.*, xii (1879), p. 24; *Memoirs G.S.*, xxii (1883), p. 264.
§ Oldham, *Manual G.I.*, 2nd ed. (1893), pp. 116, 134, 136.
|| Oldham, *Manual G.I.*, 2nd ed., p. 44; see also Lydekker, *Memoirs G.S.*, xxii (1883), pp. 263, 264.
¶ McMahon, *Records G.S.*, xvi (1883). pp. 37, 41.
** Griesbach, *Memoirs G.S.I.*, xxiii (1891), pp. 64, 65.

Though marine conditions were widespread in Carboniferous times, high land was never, in the Himalayan area, far distant from the Carboniferous seas.

In Spiti, Hundés, Perso-Afghanistan, and Jaunsar, there appears to have been an unconformity between the Carboniferous and the Permian* deposits, though those deposits are conformable to each other in the Kashmir area.† Similar instances of local unconformity in one locality of beds that follow each other with perfect conformity in another are not uncommon in Himalayan geology, and bear out a suggestion I have to make later on, that differential earth movements—the sinking of the crust of the earth in one place and its rise in another—have been a marked characteristic in the history of the Himalayas.

That the coast line of Peninsular India continued to run, during this period, in the neighbourhood of the Salt Range is evidenced by the frequent occurrence of "ripple-marks and oblique lamination" and plant impressions in the Salt Range sandstones.‡

The sea seems to have deepened towards the west and north-west, but in Afghanistan land conditions again set in; the deposits assumed a littoral character, and became carbonaceous, coaly, and "plant-bearing," and contained beds that reminded Mr. Griesbach of the Talchir conglomerates and the coal-bearing Gondwánas of Peninsular India.§

There were, doubtless, local changes of level and modifications in local conditions, such as the direction of currents, the depth of the water, or the character of the sediments, which had their effect on the marine fauna of the time; but the broad features of Himalayan geology seem to have differed little at the close of the Carboniferous period from what they had been throughout the Palæozoic era. Deep fiords seem to have run up what is now the Indus Valley into Kashmir, and along the foot of an elevated ridge of crystalline rocks; whilst another long arm of the sea flowed round the terminal end of that ridge into Spiti.

Speaking broadly, this distribution of land and sea seems to have continued the same, with probably some minor modifications, from the close of the Carboniferous to the close of the Triassic period. Remarkable deposits of marine limestones ranging from the Permian to the Trias, in apparently unbroken and conformable succession, are to be found in Kashmir, along the foot of the outer Himalayas, through Spiti, Rupshu, and the regions beyond, following the direction of the deep fiords alluded to in the last paragraph.‖ Thoughout this long period a slow but steady subsidence

* Oldham, *Records G.S.*, xxi (1888), pp. 138, 151. Greisbach, *Memoirs G.S.*, xxiii (1891), p. 228.
† Lydekker, *Records G.S.*, xiv (1881), p. 34.
‡ Wynne, *Memoirs G.S.*, xiv (1873), p. 91; *Manual G.I.* (1893), pp. 123, 124.
§ Griesbach, *Memoirs G.I.*, xxiii (1891), p. 64; *Manual G.I.*, 2nd ed. (1893), p. 197.
‖ See map accompanying *Manual G.I.*, 2nd edition.

of the areas covered by the Permo-Triassic seas must have taken place, for the total thickness of this series is very great. That of the Trias alone is estimated at 4,000 fee: in the Niti section of the Central Himalayas,* and at between 2,000 and 4,000 feet at Khanpur in Hazara.†

The volcanic forces appear to have slumbered in the Himalayan area during the Permo-Triassic period, but the occurrence of interbedded traps of Permian age in Afghánistán is recorded by Mr. Griesbach,‡ and a thickness of nearly 2,000 feet of interbedded basaltic lavas of this age§ occur in the Rajmahal series‖ which probably issued from vents now buried under the alluvium of the Ganges.

During the Jurassic period there was considerable volcanic activity in Afghánistán,¶ but none in the Himalayan area.

Jurassic-marine deposits are found on the western side of the Salt Range, but the fragments of ferns, and other plants, in some of the beds show that the shore line, in this locality, remained materially unchanged. The same remark applies to Afghanistan, where there are similar marine beds containing an abundance of plant remains.** In Kashmir, Hazára, Spiti, and in the Central Himalayas, marine Jurassic beds occur. In Hazára there is a local unconformity between the Jurassic and the Triassic systems,†† and Mr. Griesbach considers that there is a break between the Liassic and Jurassic deposits of the Central Himalayas indicated by lithological differences and by a sudden change of fauna;‡‡ which, though it does not appear to have amounted to a change from marine to terrestrial conditions, points to some important earth movements having taken place in parts of the Himalayan area during the Jurassic period.

It was probably during this period that a temporary elevation of the Permo-Triassic beds took place in the Simla-Sabathu area. Mr. Medlicott, in his survey of this area, showed that these beds were elevated and eroded before the Sabathu nummulitics were laid down;§§ the "central portion"‖‖ of the "Himalayan mountain area" having been defined before the deposition of the Sabathu nummulitic rocks.¶¶

During Cretaceous times the sea appears to have still extended up the Indus, for Cretaceous deposits are shown on the map attached to the second edition of the *Manual* at Katch, at Dehra Gházi Khán, Dehra Ismáel Khán, and near Kohát. In the Salt

* Griesbach, *Memoirs G.S.*, xxiii (1891), p. 68.
† Oldham, *Manual G.I.*, 2nd edition (1893), p. 139.
‡ *Records G.S.*, xx (1887), p. 102.
§ Oldham, *Manual G.I.*, 2nd edition (1893), p. 208.
‖ *Ib. Ib.*, 175, 176.
¶ Griesbach, *Records G.S*, xix (1886), 249; xx (1887), 102, 103.
** Griesbach, *Records G. S.*, xix (1886), 239, 248, 249.
†† Wynne, *Records G. S.*, xv (1882), p. 164.
‡‡ Griesbach, *Memoirs G. S.*, xxiii (1891), 75.
§§ Medlicott, *Memoirs G. S.*, iii (1864), pp. 75-78.
‖‖ Medlicott, *Records G. S.*, ix (1876), p. 51.
¶¶ Medlicott, *Memoirs G. S. I.*, iii (1864), p. 174.

Range marine Cretaceous fossils are doubtfully present,* whilst fossils of "decidedly Cretaceous appearance" have been found "in the area mapped as Attock slates."† In Beluchistán and Afghanistan Cretaceous marine beds are abundant; they extend to Kashmir and occur in Tibet and Hundés.‡

No volcanic rocks of lower or upper Cretaceous age are known in the Himalayas, but "the close of the Cretaceous period witnessed the great outburst of volcanic activity which buried the whole of Western India deep in lavas and ashes";§ and Mr. Oldham suggests that "it is not improbable that this great outburst may have been connected; as it was probably contemporaneous with the great series of earth movements which resulted in the elevation of the Himalayas." I very much doubt, myself, whether there was much, or indeed any, connection between the two events. The chief *foci* of the Deccan trap eruption seems to have been situated towards the south-west rather than towards the north-east; and the outpouring of the Deccan trap, which covers so enormous an area, seems to me to have been connected with the sinking of the land connection between India and Africa, which appears to have existed up to that time, rather than with the last series of earth movements which have left their marks on the Himalayas. Moreover, the two events are not synchronous. No outburst of basic trap took place in the Himalayan area during the Cretaceous period, or in Tertiary times until the deposition of the Eocene beds was well advanced; and the upper Cretaceous period must have witnessed the sinking, instead of the rising of the Simla-Sabathu area, for the Permo-Triassic beds, which had previously been elevated, and eroded, had again sunk beneath the sea before the nummulitic marine beds were deposited.

If, as the Rev. O. Fisher has given us reason to believe, every protuberance outside the crust of the earth has a corresponding protuberance projecting downwards into the fluid substratum,‖ it is hardly probable that a volcanic commotion beneath what is now the Indian Ocean would have been propagated under the roots of Peninsular India into the region of the Himalayas.

The outpouring of the Deccan trap set in at the close of the Cretaceous period, but the "special disturbances" which marked the last phase of the history of the Himalayas did not set in until the close of the Eocene epoch.¶ During Eocene times the sea "flowed over Western Rajputana and the Indus valley to the west, over a large part of Beluchistan, and Afghanistan, and over the whole of the north-west Panjab and the outer Himalayas as

* Wynne, *Memoirs G. S. I.* (1878), p. 104.
† *Manual*, 2nd ed. (1893), p. 116.
‡ Stoliczka, *Memoirs G. S.*, v (1866), p. 116; Griesbach, *Memoirs G. S. I.*, xx (1887), pp. 99, 100; *Memoirs G. S.*, xxiii (1891), pp. 81, 82.
§ Oldham, *Manual*, 2nd edn. (1893), p 494.
‖ *Physics of the Earth's Crust*, 2nd ed. (1889), pp. 184, 195.
¶ Blanford, *Manual G.I.*, 1st ed. (1879), lvi.

far east as the Ganges River. . . . Sea also flowed over the central Himalayas and was probably continuous with that just referred to, across the north-western termination" of the range*. In other words, the Himalayan land and sea boundaries, in their broad general features, remained much the same during the Eocene epoch as during the Permo-Triassic period. "An arm of this sea," in the words of Dr. Blanford, "extended from the north-west up the upper Indus valley in Ladák. The Himalayas, and perhaps Tibet, wholly or in part, were raised above the sea."† Another arm of the sea ran along the south of the Himalayas as far as the Ganges.‡ Beds of impure coal at Sabathu, in the Salt Range, and in various parts of Afghanistan, indicate clearly enough the proximity of the shore-line during this period to the places where these coaly deposits are now found.

It was not until the close of the Eocene epoch that the crumpling up of the strata on both sides of the ancient axis of crystalline rocks took place, and that the steady rise of the *whole* Himalayan area began which has been going on ever since.§ When this period of continued elevation set in the fiords of the Eocene sea began to shrink up from east to west; and the sea gradually retreated from the Himalayan area, and from the Panjab. The drainage followed the contracting seas, and the rivers of the ancient land gradually increased in volume and importance, and established themselves along their present lines. The Simla-Sabathu area became the water parting between the Ganges and Panjab river-systems. The river Jumna at first yielded allegiance to the one but eventually turned over to the other.

At this point a very interesting question arises. Can we obtain any clue to the cause, or to the agent, which was principally concerned in inaugurating the last series of Himalayan earth movements which set in at the close of the eocene epoch?

I have already given my reasons for thinking that these movements were not connected with the eruption of the Deccan trap. The eruption of basic lavas formed, we have seen, a striking element in Himalayan geology during the Silurian and Carboniferous periods. After their close volcanic activity connected with the outpouring of basic lavas declined in the Himalayan area. The history of the plutonic forces connected with an acid magma appears to have been different. Granitic eruptions into the deposits covering the Himalayan area appear to have begun early and to have continued into comparatively late geological times. The Vaikritas (old crystalline series) are completely riddled with

* Oldham, *Manual G.I.*, 2nd ed. (1893), p. 494. See also Dr. Blanford on "Probable Shore of the upper Cretaceous Sea in Sinde and Salt Range," *Manual G.I.*, 1st ed. (1879), p. l.

† *Manual G.I.*, 1st ed. (1879), p. liii.

‡ *Ib.* p. lii.

§ Blanford, *Manual G.I.* (1879), p lvi; McMahon, *Records G.S*, xviii (1885), p. 81; Griesbach, *Memoirs G.S.I.*, xxiii (1891), pp. 34, 227; Oldham, *Manual G.I.* (1893), p. 485.

a granite, which not only occurs in intrusive dykes and veins, but wells up in great masses, and forms some of the loftiest Himalayan peaks.* Granite is also intrusive in the lower Palæozoic series;† in the Carboniferous series‡ of the Satlej basin; invades the Permo-Carboniferous series in Afghanistan;§ Triassic rocks in Kashmir‖; and the Cretaceous,¶ and Eocene,** in Afghanistan.

The granite of the snowy peaks formed part, doubtless, of a very ancient eruption,†† for, as we have seen, granite was undergoing erosion from an early period; and that it was directly connected with the elevation of the axis of crystalline rocks in the Cambrian period, the worn stumps of which now form the line of snowy peaks, seems probable. However this may be, I cannot escape from the conclusion that the contortion, compression, and upheaval which marked the earth movements that set in at the close of the Eocene period, were connected with the intrusion of the gneissose granite.

There is no evidence to show that this granite found a free vent at the surface on an extensive scale; had it done so effective relief to the plutonic forces would have been obtained; the work done in crumpling and upheaval would have been less; and the marks of the struggle left on the granite itself would not have been so severe.

Had an extensive outflow of acid lava taken place, evidence of it would have been left in the form of lava streams, or ash beds, intercalated with the Tertiary strata, which is not the case, and the relief afforded to the plutonic forces by an extensive surface outflow might have been followed by a period of subsidence.

That the granite may, in one or two instances, have reached the surface is possible, for Mr. Middlemiss‡‡ found rhyolitic lavas in Garhwál, and rocks intermediate in *structure* between them and the gneissose granite.

There is no evidence, however, that Mr. Middlemiss's Lobah volcanic rocks are of Tertiary age, and there is no direct connection between them and his Dudatoli granite. The granite and the lavas may, therefore, be of different ages, and the lavas may be older than Tertiary.

That the gneissose granite in not younger than early Miocene can hardly be doubted. Boulders of it are very plentiful in the

* Strachey, *Q.J.G.S.*, vii (1851), p. 301; McMahon, *Records G.S.I.*, xii (1879), pp. 60-62; Griesbach *Memoirs, G.S.I.*, xxiii (1891), pp. 40-48.
† Griesbach, *l.c.*, 42, 44, 48.
‡ Oldham, *Records G.S.I.*, xxi (1888), p. 149.
§ Griesbach, *Records G.S.I.*, xix (1886), p. 241.
‖ Lydekker, *Records G.S.I.*, xiv (1881), p. 14.
¶ Griesbach, *Memoirs G.S.I.*, xviii (1881), pp. 3, 48; *Records G.S.I.*, xix (1886), pp. 64, 242; xx (1887), pp. 22, 23.
** Griesbach, *Records G.S.I.*, xx (1887), pp. 102, 103.
†† Strachey, *Q.J.G.S.*, vii (1851), p. 309.
‡‡ *Records G.S.I.*, xx (1887), p. 161.

upper Pliocene Siwâlik conglomerates of the outer Himalayas, showing that it had been erupted, consolidated, and exposed at the surface, when the Siwâliks were laid down.

I see no ground, on the other hand, for the supposition that the granite of the outer Himalayas is older than the close of the Eocene epoch. The Eocene strata were not contorted until after the deposition of the Miocene beds had gone on for some time, and all the field evidence, so far as I am acquainted with it,* supports the view that the intrusion of the main mass of the granite was contemporaneous with the folding and faulting of the strata which took place in Miocene times. The granite, though it appears in different horizons, and varies greatly in thickness, swelling out sometimes, in the parts of the Himalayas with which I am conversant, to a width of twelve miles,† runs, on the whole, with the strike of the sedimentary rocks, and its outcrop seems to be directly connected with the wrinkling of the strata and the formation of overthrust faults. It appears all along the southern flank of the Himalayas from Kashmir, in the north-west, down to Kamaun, beyond which the geological map is almost a blank down to Sikkim.

The intrusion of so great a thickness of igneous rock for nearly the whole known length of the Himalayas must have assisted very materially to produce, if it were not the sole cause of, the great compression of the strata which took place in middle Tertiary times; and if its eruption had occurred prior to the crumpling it would surely not have run with the strike of the folds produced by that crumpling. Thin sheets of granite might conceivably have been folded up with the crumpled strata; but when one sees not only thin sheets, but long outcrops twelve miles thick, implicated in the folding in a way to suggest intrusion along overthrust faults, this explanation becomes highly improbable.

Numerous sections would be required to fully illustrate the folding and faulting which resulted from the compression of the strata, and the intrusion of the granite; but I give below (p. 94), by way of sample, a section drawn to illustrate one of my papers on the geology of Dalhousie, reproduced, with the kind permission of the Director of the Geological Survey of India, from the plate facing p. 110, vol. xviii, *Records G.S.I.*

During the Eocene epoch volcanic activity was rekindled to a limited extent in Kashmir,‡ the Central Himalayas, and in

* Mr. Middlemiss mentions the case of the Gola River and Kotudwar granite (*Memoirs G.S.*, xxiv. (1890), p. 114), and argues that the granite there must be pre-Tertiary because the Tertiary beds are not metamorphosed. But as the distance of the granite from the Tertiaries in one case appears to be five miles, this argument does not carry us far. But even if the particular outcrops of granite alluded to are pre-Tertiary, that does not show that the main mass of the gneissose granite, so extensively seen in the outer Himalayas, is not post-Eocene. I have shown that the porphyritic granite was preceded by a finer grained granite. See *Records G.S.I.*, xvii (1884), p. 35

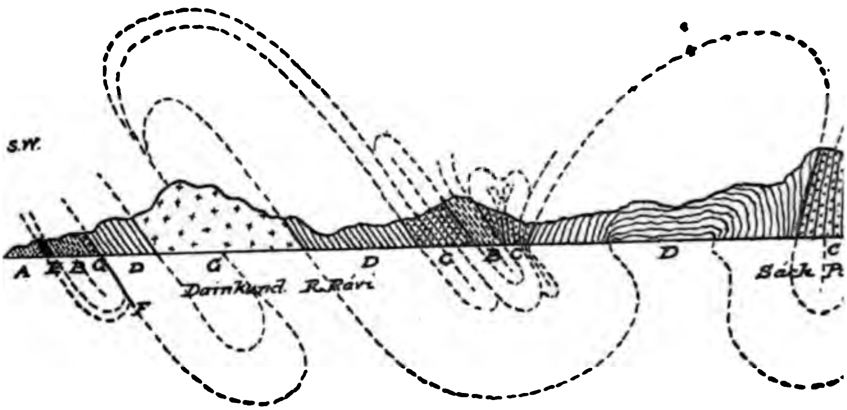
† It attains this width in the Dalhousie area (see map attached to *Records G.S.I.*, xviii, p. 110), and probably exceeds it in some places farther to the east.

‡ Lydekker, *Memoirs G.S.I.* xxii (1883), p. 41.

Afghanistan*; but in post-nummulitic times basic, and ultra-basic, igneous rocks (gabbros, peridotites, etc.), were erupted in some abundance, and had a powerful metamorphic action on the nummulitic strata.† Like the granite these basic intrusive rocks "appear along lines of dislocations and here and there enter the neighbouring strata as dykes.‡

All the above instances of the occurrence of Tertiary basic trap within the Himalayan area occur either in Kashmir or on the farther side of the Himalayan crystalline axis. All along the southern flank of that axis the great eruption of the gneissose granite appears to have taken the place of the basic trap.

Time would fail me were I to attempt to enter into the many interesting branches of inquiry suggested by the above brief sketch of a complicated subject. The physics of the question



SECTION THROUGH DAINKUND TO THE SÁCH PASS.

A. Tertiary series. B. Permo-Triassic series. C. Conglomerates. D. Silurians
E. Traps. G. Gneissose granite. F. Fault.

Longitudinal Scale—1 inch = 10 miles.

must necessarily be left untouched. The zoological and palæontological sides must also remain unnoticed. I would only refer, in passing, to Dr. Blanford's able and highly interesting paper in the *Geological Magazine* on the bearing of the zoological aspects of the case on the question of the age of the Himalayas. After referring to the peculiar forms of animal life in Tibet, he writes: "I must say that it is to me incredible that this

* Griesbach, *Records G.S.I.* xix (1886), p. 64, xx (1887), pp. 99-102.

† Griesbach, *Records G.S.I.* xiii (1880), p. 91. Lydekker notes a vein in the vicinity of the nummulitic area, but it occurs, I gather, in a band coloured "Krol, infra Krol, and Blaini;" viz., in pre-Triassic rocks; *Memoirs G.S.I.* xxii (1883), pp. 112-113-105 (fig. 7); McMahon, *Records G.S.I.* xix (1886), page 116; Griesbach, *Memoirs G.S.I.* xxiii (1891) pp. 45, 84, 130.

‡ Griesbach, *Memoirs C.S.I.* xxiii (1891), p. 45.

peculiarly specialized fauna can have been differentiated since Pleistocene times; and very improbable that it can have been entirely developed since the Pliocene period. So high a degree of specialization points to a long continuance of the peculiar conditions that still prevail." *

The conclusion arrived at by the author of the article on the Himalayas (General Strachey) in *The Encyclopædia Britannica* is that "an area of land must have existed where the line of snowy peaks now stands, which has not been submerged since the Palæozoic period." A study of the geological evidence has landed me in a similar conclusion, from which I see no escape, and the evidence for which, as at present known, I have endeavoured to lay before you this evening.

From the Cambrian down to the close of the Eocene epoch the Himalayas have, it seems to me, presented very similar conditions to those seen to-day in the Malay archipelago—long chains of mountainous islands alternated with deep, narrow seas, the margins of which were fringed with active volcanoes.

The lavas poured out during the Silurian and Carboniferous periods are generally supposed to have been submarine. My impression is that the volcanoes were on land and that their lavas and ashes were deposited partly on land and partly within the littoral line of the sea. I know of no contemporaneous lava flows intercalated with deep sea limestones.

We seem to have had side by side, for long periods, sinking areas covered by sea and rising areas crowned by mountains. That such areas should have existed side by side seems to me only what one might have expected to see. If there is one fact in geology which I believe to be more firmly established than any other it is that where the crust of the earth is loaded with deposits a sinking of the crust takes place, for we see this process going on at the mouth of every great river. The converse of this proposition seems also true, namely, where the load is removed the tendency of the lightened area is to rise: instance the "creep" in our mines. In the case of the Himalayan archipelago —as I read the story—pluvial, and other agents of erosion, acting through long periods of time, gradually wore down the surface of the mountain area and caused a gradual rise proportional to the load removed, whilst the eroded material carried by the streams and rivers into the adjoining narrow seas caused their gradual subsidence. The planes between the sinking and the rising areas, were, I take it, faults with throws many thousands of feet in extent.

That the earth-movements connected with the infancy and youth of the Himalayas were *mainly* simple movements of elevation and depression, unaccompanied by considerable tangential

* *Geol. Mag.* (1891), 374.

compression, seems certain.* Indeed, it is the general absence of the marks of crushing and contortion of an earlier date than Miocene times that has led so many geologists to forget that the careworn Hima-álaya, whose brow now bears so many wrinkles, ever had a placid infancy and youth.

But a time of trial and trouble for our Hima-álaya came at last. The subsidence of the areas covered by sea came to an end, and both areas—those crowned by mountains and those covered by sea—rose together. The period of general elevation that then set in appears to have been connected with a revival of plutonic activity, for it was a time of granitic eruption on a grand scale—a time when the beds on either side of the chain of crystalline rocks suffered great contortion and crushing.

During the slow and majestic elevation of the Hima-álaya, the direction of the rivers seems to have been determined partly by the folding of the strata in long S.E. to N.W. flexures, and partly by the character of the rocks; the rivers escaping to the plains wherever the barrier opposed to them showed signs of weakness. For instance the Rávi runs parallel to the Dhula Dhár, where the granite is from eight to twelve miles thick; but where it is temporarily reduced to a width of 250 feet, the river turns suddenly and rushes down to the plains. The Jhelam river is another case in point. It escapes from the vale of Kashmir where the granite does not oppose its course. The rock is seen on both sides of the river, but not, apparently, in its bed.

The thinness, or the absence of the granite at some points, indicates that the elevatory force was comparatively feeble there, and local depressions favourable to the escape of the rivers were probably the result.

In conclusion I would remind anyone who may think it improbable that the same conditions should have prevailed in the Himalayan archipelago for so long a period, that the case of Peninsular India is even more remarkable, for the land of the dark Hindu (Hindu-istán) does not appear to have had a dip in the sea since the close of the Palæozoic era.† Our fair lady Hima-álaya, has had, at all events, more respect for the laws of beauty and of sanitation.

* Medlicott, *Memoirs G.S.I.*, iii, pt. ii (1864), p. 86.
† Oldham, *Manual G.I.*, 2nd ed. (1893), p. 2.

VISIT TO THE ROCK GALLERY, MUSEUM OF PRACTICAL GEOLOGY, JERMYN STREET.

SATURDAY, 23RD MARCH, 1895.

Director: W. W. WATTS, M.A., F.G.S.

(*Report by the* DIRECTOR.)

The purpose of the collections in this room is to illustrate the rocks which occur in Great Britain, their characters, and their origin. The first case to which attention was called contains rock-forming minerals arranged under the heads of essential constituents, accessory constituents, and secondary constituents. Case B contains a collection of typical rocks, not only British but Foreign as well. Case C shows the various structures found in rocks of all classes, due either to processes taking place while the rock was actually forming, or to subsequent changes brought about during or after the consolidation of the rock. Case D is intended to illustrate the modifications which rocks undergo owing to the action of either deep-seated or surface agencies.

The greater part of the room is occupied with the great collection of British rocks gradually accumulated during the progress of the Geological Survey, the older portion of which was fully catalogued and described in the catalogues written by various members of the Survey when Sir Andrew Ramsay was Director-General. This collection is now arranged in stratigraphical order in the wall-cases which stand round the room and in four large pedestal-cases at the four corners of the room. The rocks of each System have been arranged by the members of the staff best acquainted with that System. Within the systematic grouping the rocks have a topographical arrangement, so that all the rocks from a particular district, of about the same age, will be found in close proximity, the igneous rocks being placed near the sedimentary and foliated rocks. Attention was drawn to the large sections and photographs now placed in the room.

EXCURSION TO HAMPSTEAD.

SATURDAY, 30TH MARCH, 1895.

Director: A. M. DAVIES, B.Sc., F.G.S.

(*Report by the* DIRECTOR.)

The party assembled at Finchley Road Station at 3 p.m., and started northwards towards Frognal. At the start the Director called attention to the typical London Clay exposed in the foundations of some new houses. Turning up Frognal Lane, the way was taken to Redington Road, where a halt was called at the

beginning of the footpath leading to Oakhill Park, at a height of about 350 feet above O.D. Here there was an exposure of the sandy clay that forms the uppermost beds of the London Clay, and the Director took advantage of the halt to give a short account of the general structure of the district. Turning up the footpath, a point was soon reached where the cutting showed plainly the exact junction between the sandy clay and the Bagshot Sands. The latter beds alone were seen from this point onwards to the summit of the Heath, though the abundant flint pebbles noticed in the paths represented the down-wash from Drift-deposits at the top. From the summit of the Heath the extensive view included the heights of Highgate and Harrow, which, like Hampstead, are Bagshot outliers, and the gravel-capped Stanmore Heath. Some diminutive exposures here showed gravel with flint and quartz pebbles resting on the Bagshot sands, and further signs of these were seen on the eastern side of the Spaniards Road, where the discovery of abundant chert pebbles led to an interesting discussion on the age and derivation of the various gravels of the London district.

Just beyond the Spaniards the road begins a sharp descent to the London Clay ground, and on the right, at the southern end of Kenwood Farm grounds, is the finest section of the Bagshot sands to be found in the neighbourhood. By kind permission of the Express Dairy Company, the Association was able to visit this sandpit. The sands were beautifully false-bedded, and stained red and yellow, with clayey partings. In a few places a curious vertical ripple, like iron-staining, was seen to cross the lines of false-bedding. No explanation of this, beyond the unsatisfactory "infiltration," could be offered. The Director mentioned that he had found here some small hollow ironstone concretions, but none were found on the present occasion. It is probable that this section reaches down to the base of the sands, but the lower part was hidden by talus.

The party next descended the hill farther, in the hope ot finding exposures of the London Clay in some new house foundations, but without success. It, therefore, separated here, some returning to Hampstead, others to Highgate.

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See also "Record of Excursions," pp. 140 to 144.

EXCURSION TO THE TERTIARY BEDS OF THE ISLE OF WIGHT.

EASTER, 1895.

Directors: R. S. HERRIES, M.A., F.G.S., AND H. W. MONCKTON, F.L.S., F.G.S.

(*Report by the* DIRECTORS.)

The object of this excursion was to enable the members of the Association to compare the magnificent sections through the Tertiary Beds at the east and west ends of the Isle of Wight with those on the mainland, visited at Easter, 1894.* This was the first time that the sections at both ends of the island had been visited by the Association in one excursion.

The headquarters were at Child's Hotel, Sandown, where the majority of the members assembled on the evening of April 11th.

Friday, April 12th.—On the first day of the excursion, the party, some sixty in number, starting at ten o'clock, walked along the shore towards the Culver Cliff, Mr. Monckton acting as director.

About a mile from Sandown the party halted at a breakwater, and the Director made some general observations on the physical geology of the Isle of Wight. He described the great anticline on the south and the corresponding syncline on the north—the axis in both cases running east and west. In illustration of his remarks, he pointed to the beds of the Lower Greensand on the opposite (south) side of Sandown Bay, which were seen to have a southerly dip, whereas the beds on the Culver Cliff side dipped north. The party had, in fact, walked over the top of the anticline, which was in this instance the lowest part of the coast. This fold was clearly caused by the same series of movements that affected the coast of Dorset, and the Isle of Wight was, the Director thought, probably at no very distant time connected by land with the Isle of Purbeck.

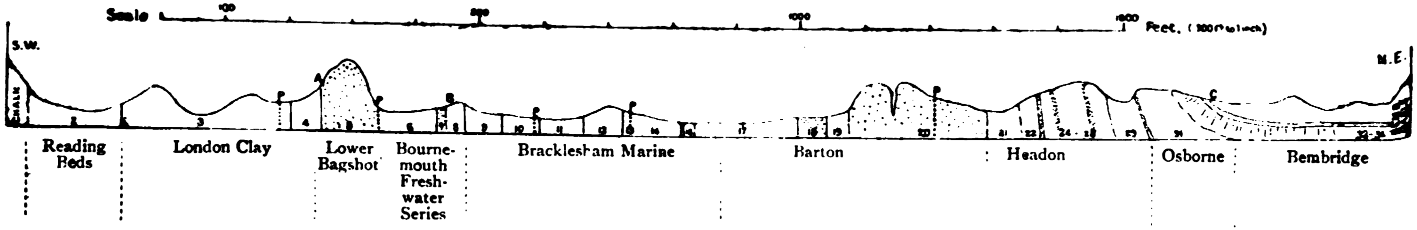
On the north side of the anticline the strata dipped at a higher angle than on the south, and, in consequence of the high dip, the beds from the Weald Clay to the Bembridge Marls inclusive would be seen during the day, whereas it took four days at Easter, 1894, to examine the beds from the Wealden at Swanage to the Headon at Hordle.

A short time was spent in collecting from the Wealden shales which in places were found to be crowded with Cyprids, while some thin bands of limestone furnished specimens of *Paludina* and *Cyrena*. After Mr. Leighton had given a short account of the Lower Greensand of the locality, the walk was resumed as far as the outcrop of the Upper Greensand, where the party ascended

*Proc. Geol. Assoc., vol. xiii (1894), p. 274

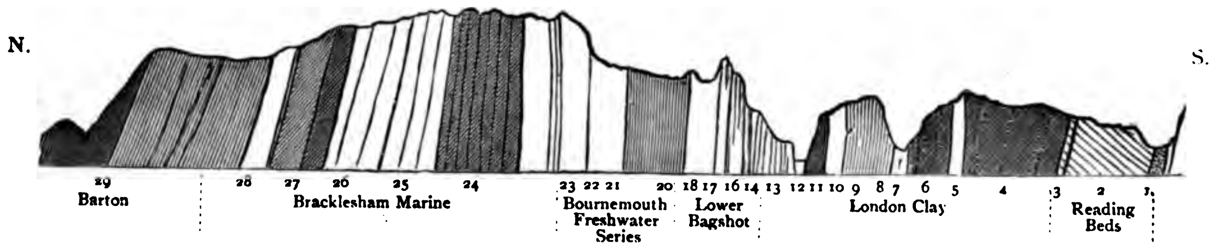
the cliff, and, crossing Culver Down, descended by a path into Whitecliff Bay. Mr. Monckton then made some general remarks on the magnificent section here seen. On the south side was the Chalk in a nearly vertical position, forming Culver Cliff, and succeeding it the whole of the Eocene Beds, and the Oligocene Beds up to and including the Bembridge Marls were exposed successively in the cliff within the confines of this small Bay. (See Fig. 1.) Proceeding northwards the party examined the Tertiary Beds in detail, the Director describing the principal points in each. The mottled Woolwich and Reading clay (Bed 2 of Fig. 1) was well shown, but no fossils were found in it; indeed, so far as Mr. Monckton knew, none but Ostracoda and plants have been found in this formation in the Isle of Wight. The basement bed of the London Clay yielded *Ditrupa plana* and several casts of bivalves. Nos. 3 and 4 of Fig. 1 represent the London Clay, and the Director pointed to the intercalation of grey and yellow sands between beds of undoubted London Clay as affording evidence in favour of the opinion of Mr. Starkie Gardner, that the grey sandy beds at Alum Bay (Nos. 7 to 13 of Fig. 2) should also be included in the London Clay. The Lower Bagshot at Whitecliff Bay (No. 5 of Fig. 1) is a sand with a well-marked layer of iron sandstone at the base, and with a pebble-bed nearly a foot thick at the top, separating it from Nos. 6, 7, and 8, which Mr. Starkie Gardner correlates with his Bournemouth Freshwater Series, taking the greenish clayey bed, with layers of *Cardita*, No. 9, as the base of the marine part of the Bracklesham Beds, the sub-divisions of which by Prof. Prestwich and the Rev. O. Fisher were explained by the Director (see *Quart. Journ. Geol. Soc.*, vol. xviii, p. 65). Many fossils were obtained from bed 9 and a quantity of *Nummulites lævigatus* from bed 12. The waterworn condition of many of the fossils in bed 13 was remarked, and the party proceeded to collect from Nos. 14 and 16, the small Nummulite, *N. elegans* (variety *variolarius*), being found in great abundance. After luncheon the approximate position of the zone of *Nummulites elegans* (variety *Prestwichianus*) was pointed out in the lower part of bed 17, though owing to the overgrown and obscure condition of this part of the section this zone can seldom if ever be seen, except on the foreshore, where it was discovered by Mr. H. Keeping in 1886, and described by him in the *Geol. Mag.* Dec. 3, vol. iv, p. 70. This zone, which occurs also at Alum Bay and Highcliff, is a fairly satisfactory base for the Barton series, and it almost coincides with the disappearance of nummulites in the British area.

The conspicuous bed of sand, No. 20 of Fig. 1, was next examined, and the Director explained that it corresponded to the white sands north of the pier at Alum Bay (see Fig. 3), and to the Becton Bunny Beds and Long Mead End Beds of Hordle



P = Pebble Beds.

FIG. 1.—SECTION AT WHITECLIFF BAY.—*W. Topley (after J. Prestwich).*



The numbers of the beds in this section and the one above are those used by Professor Prestwich.

FIG. 2.—SECTION AT ALUM BAY.—*J. S. Gardner.*

(see the folding plate *Proc. Geol. Assoc.*, vol. xiii, 1894, p. 280). This bed has usually been called the Upper Bagshot, but that name must be used with caution, since the beds also ca led Upper Bagshot in the London basin are at the base of the Barton series instead of at the top. Messrs. Gardner, Keeping, and Monckton, therefore include these sands, as well as those on the same horizon at Alum Bay and Hordle, in the Barton series (see *Quart. Journ. Geol. Soc.*, vol. xliv, p. 578).

The Eocene ends here and the Oligocene begins with the Headon beds, of which the Upper and Lower divisions are fresh-water and the Middle division marine. The latter contains two well-marked zones of fossils, the lower of which has been correlated by the Rev. O. Fisher (*Quart. Journ. Geol. Soc.*, vol. xviii, p. 67, note) with the Brockenhurst zone of the New Forest, whilst the upper is probably the representative of the well-known "Venus Bed" (Middle Headon) of Colwell Bay and Headon Hill. Many fossils were found here, including *Cytherea incrassata* (the *Venus* of old collectors), *Murex sex-dentatus*, *Natica*, *Voluta*, etc.

The Osborne series, which succeeds, consists of Mottled Clays of freshwater origin, and they are overlain by the Bembridge Lime-stone, and here a change takes place in the dip of the beds, which have hitherto been vertical or nearly so, for the Limestone appears in the cliff, dipping at an angle of about 45°, and then curves round into a nearly horizontal position, spreading out into reefs on the foreshore. Besides the characteristic freshwater shells, *Paludina*, *Limnæa*, and *Planorbis*, a search was made in the lime-stone for land shells, and several specimens of *Helix vectensis* were found. The oyster bed at the base of the Bembridge Marls was then noticed. During the afternoon tea was obtained at the Hotel, and eventually the party returned to Sandown by the cliff.

On *Saturday, April 13th*, the party left Sandown by train at 8.27 for Freshwater, under the direction of Mr. R. S. Herries, being joined at Newport by Mr. G. W. Colenutt, of Ryde, so well-known for his researches in the Oligocene Beds of the Isle of Wight. The route taken was by Totland Bay and over Headon Hill to Alum Bay, giving the members an opportunity of seeing the upper beds of Headon Hill. A fairly good exposure of the Bem-bridge Limestone was visited, and several specimens of the large *Bulimus ellipticus*, as well as *Helix vectensis* and *Limnæa* were obtained. Mr. Colenutt also drew attention to the curious con-cretionary bodies thought by Edwards to be turtles' eggs. Below the Bembridge limestone the broken slopes of the Osborne beds were seen, red and green marls, while below were two terraces of limestone, the higher of which, containing but few fossils, is classed with the Osborne Beds, and is separated from the one below by green marls of the Upper Headon series.

This lower terrace is the well-known *Limnæa*-limestone of the Upper Headon, which makes such a conspicuous feature in all views of Headon Hill. Resuming the walk, a fine section of plateau gravel was seen, but the talus quite obscured the Bembridge Limestone which is sometimes seen at this point. Before descending to the shore at Alum Bay, the Director called the attention of the members to the grand view of the Hampshire and Dorset coast, the scene of last Easter's operations. Right opposite to the Needles, which were conspicuous on the south side of the Bay, was the chalk headland of Ballard Point, with the Lower Cretaceous, Wealden, and Jurassic Beds of Swanage Bay and Durlston Head to the South, while the long low sweep of the Tertiary beds of Studland Bay and the Hampshire coast stretched away to the North and East, broken by Hengistbury Head, and ending in the shingle spit of Hurst Castle just opposite the spectators. In Alum Bay the Director pointed out the similarity to Whitecliff Bay, the verticality of the beds being due to the same causes, though here the vertical bedding only extends to the top of the Eocene, the beds in Headon Hill, though they have a considerable northerly dip, appearing almost horizontal, owing to the trend of the coast becoming nearly East and West, or parallel, to the direction of the strike. The party proceeded to the South side of the bay and began to examine the beds in detail, from the Woolwich and Reading upwards (see Fig. 2). The junction with the Chalk was well shown; the mottled clays which form the greater part of the Reading Beds, being separated from the chalk by a few feet of coarse sand, with an irregular layer of flints at the base.

Divisions 4, 5, and 6 of Fig. 2, consisting of two beds of dark brown clay, with a bed of yellow sand between them, represent the London Clay of the Geological Survey and others, but Mr. Starkie Gardner considers that Nos. 7 to 13, consisting for the most part of light yellow and grey sands, which have generally been classed with the Lower Bagshot, also belong to the London Clay, giving as his reason their similarity to the sands of No. 5, and to beds which have already been described as occurring in the London Clay at Whitecliff Bay. (*Proc. Geol. Assoc.*, vol vi, p. 83.) Then follows a series of sands, bright yellow, white, red, pink, and brown—the well-known coloured sands of Alum Bay—interrupted by two thick beds of clay, Nos. 20 and 24. The whole series, from Nos. 7 to 26, is called Lower Bagshot by the Survey, but Mr. Starkie Gardner confines the Lower Bagshot to Nos. 14 to 18, and in this series in bed 17 occurred the well-known Alum Bay leaf-bed, the position of which was pointed out by the Director, who said that it was probably lenticular and had now thinned out. There are several seams of pipe-clay on this horizon, but nothing was found in them except some stalk-like impressions. Mr. Gardner considers divisions 19 to 23 to be the

equivalent of the Bournemouth Freshwater Series, while, according to him, the Marine Bracklesham Beds include the beds from 24 to the *Nummulites Prestwichianus* zone, 47 feet above the base of bed 29 (see Fig. 3). The Survey adopts the same upper limit for the Bracklesham, but places the base at the top of bed 26, while Mr. Fisher did not take it below the base of bed 29.

The divisions adopted by the Survey have, it is true, a certain convenience on their side, for they confine the London Clay to the dark brown clays below the sandy series, and they keep all the coloured sands—which, except for leaves, are entirely unfossiliferous—in one division, viz., the Lower Bagshot; but when we come to compare the beds with those at Whitecliff Bay we are met by the suspicious circumstance, that whereas the total thickness from the base of the London Clay to the top of the Bracklesham is much the same, there is an extraordinary discrepancy in the thickness of the component beds, and the advantage of Mr. Gardner's arrangement becomes apparent, as will be seen from the following tables, in which the Survey measurement of the beds has in each case been adopted:—

SURVEY DIVISIONS.	ALUM BAY.	WHITECLIFF BAY.
	Feet.	*Feet.*
Bracklesham	*155	†570
Lower Bagshot	662	98
London Clay	233	320
	1,050	988

MR. STARKIE GARDNER'S DIVISIONS.	ALUM BAY.	WHITECLIFF BAY.
	Feet.	*Feet.*
Bracklesham Marine	*419	†447
Bournemouth Freshwater	152	123
Lower Bagshot	76	98
London Clay	403	320
	1,050	988

Whichever grouping is adopted, the fact remains that the beds have undergone a great change of character between the east and west ends of the island, unfossiliferous sands being developed at Alum Bay in place of the great deposits of clay full of marine shells at Whitecliff Bay, but if Mr. Gardner is right, the other difficulty, viz., the variations in thickness of the beds, is at any rate got over.

At the base of Bed 24 Mr. St. Barbe drew attention to a

* Including 47 feet of Bed 29, Fig. 2.
† Including 80 feet of Bed 17, Fig. 1.

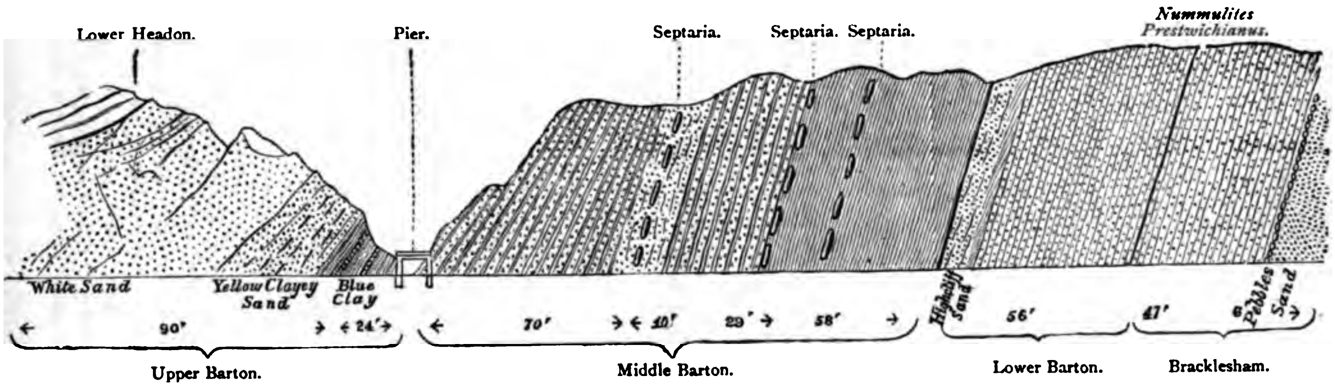


FIG. 3 —SECTION OF THE BARTON BEDS AT ALUM BAY.—*Gardner, Keeping, and Monckton.*

Reproduced, by permission, from *Quart. Journ. Geol. Soc.*, Vol. xliv.

dark clayey seam associated with lignite and full of leaf remains, which he had recently discovered. Some of the leaves seem to be almost perfect, but the clay breaks up so easily, that it was found almost impossible to preserve good specimens. The layers of lignite in bed 27 were noticed, and Mr. Leighton pointed out the rootlets piercing the under-clay as in the Coal Measures. Bed 28 is divided from the one above by a pebble-bed 6 inches thick, 47 feet above which is the base of the Barton, marked by the zone of *Nummulites Prestwichianus* (Fig. 3). Several layers of septaria were noticed in the Barton Clays, which extend as far as the pier. An adjournment was then made for luncheon, and on the way up to the Hotel a good exposure of the zone of *N. Prestwichianus* was pointed out on the North side of the chine, the occurrence of that fossil there having been lately noticed by Mr. St. Barbe.

After luncheon the party assembled on the spur on the north side of the chine, overlooking the gap caused by the digging away of the white sands, known as the Headon Hill Sands, for purposes of glass-making. These sands, the Director explained, were also known as Upper Bagshot. They were not, however, the equivalent of the Upper Bagshot of the London Basin, as Mr. Monckton had pointed out when speaking of the corresponding bed in Whitecliff Bay. They have been grouped by some observers with the beds above, but Messrs. Gardner, Keeping, and Monckton (*Quart. Journ. Geol. Soc.*, vol. xliv, p. 578) consider that they form part of the Upper Barton Series. Across the gap, resting on the white sands, with a gradually diminishing dip, a series of limestones alternating with marls was seen. These are the lower beds of the Lower Headon, and when the limestones were examined some of them were found to contain seeds of *Chara*, just as the similar beds at Warden Cliff do (Fig. 5). Professor Blake (*Proc. Geol. Assoc.*, vol. vii, p. 159) makes out that there is a considerable fault at this point, but the Directors were not able to agree with him, though a little farther on there is a slight dislocation of the beds in the upper part of the cliff, as shown in Prestwich's figure. (*Quart. Journ. Geol. Soc.*, vol. ii, p. 223.)

The party then proceeded slowly along the under-cliff of talus that forms the base of Headon Hill, collecting from the rich marine Middle Headon Beds or the fallen blocks of the fresh-water Upper Headon limestone as they went. The section of the hill from the *Limnæa* limestone downwards is sufficiently shown in Fig. 4, reproduced from Messrs. Keeping and Tawney's paper, but the state of the talus only allows an examination of the section at rare intervals. Among other fossils, there were obtained *Limnæa longiscata*, *Paludina lenta*, *Planorbis*, *Potamomya* and a crocodile tooth from the Upper Headon, and *Ostrea velata*, *Cytherea incrassata*, *Cyrena obovata*, *Cerithium concavum*, *C. ventricosum*,

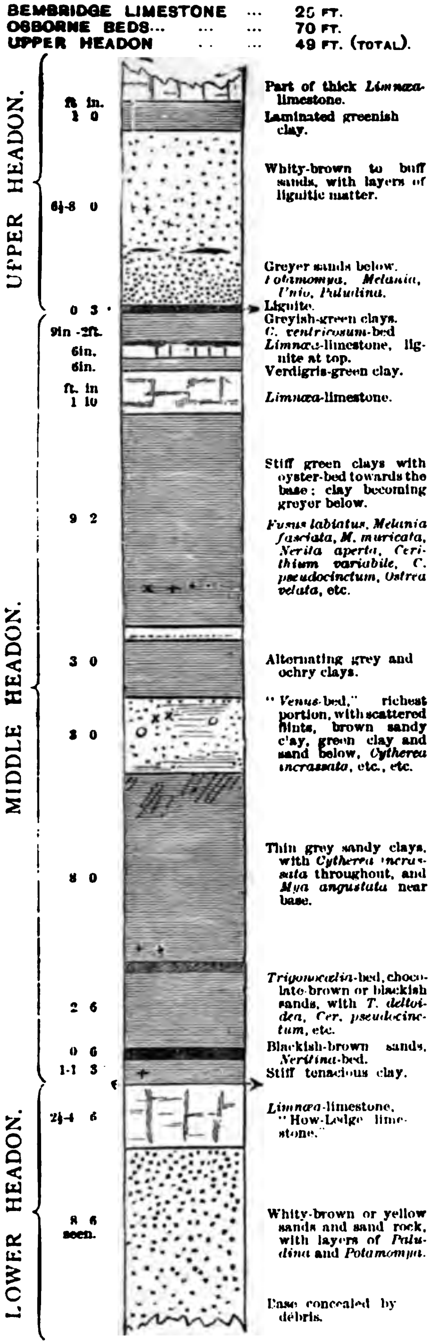


FIG. 4.—VERTICAL SECTION OF BEDS AT THE N.E. CORNER OF HEADON HILL. (Scale 8ft. = 1 in.)—*Keeping and Tawney*.

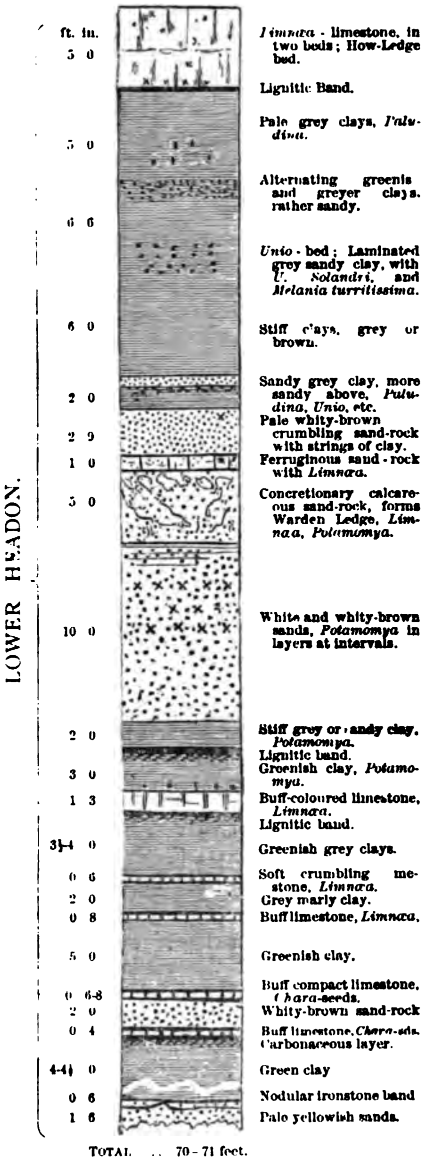


FIG. 5.—VERTICAL SECTION OF LOWER HEADON (FRESHWATER) BEDS EXPOSED BETWEEN WESTON CHINE AND WARDEN CLIFF. (Scale 12 ft. = 1 in.)—*Keeping and Tawney*.

For full particulars of these sections see *Quart. Journ. Geol. Soc.*, vol. xxxvii, pp. 91 and 98, from which they are, by permission, reproduced.

C. pseudocinctum, *Buccinum labiatum*, *Melanopsis fusiformis*, *Neritina concava*, and *Natica* from the Middle Headon. When the party had arrived at a place commanding a view of Totland Bay, and Colwell Bay beyond, the Director called a halt and gave a short account of the controversy that arose on the publication of Professor Judd's paper in 1880. (*Quart. Journ. Geol. Soc*, vol. xxxvi, p. 137.) He reminded the members that Professor Judd, mainly in order to account for certain palæontological differences between the Middle Headon Beds of Headon Hill and Colwell Bay, suggested that the bed known as the Venus Bed at Colwell Bay was possibly not of the same age as the bed at Headon Hill with which it has been correlated by other writers, but that it was considerably newer and the equivalent of the Brockenhurst zone of the New Forest, whilst the beds at Headon Hill represented the *Cerithium concavum* beds of the Paris Basin. The old view was supported by Messrs. Keeping and Tawney in a paper published in 1881,* and Mr. Herries thought that they had shown that from a stratigraphical point of view Professor Judd's theory was untenable, which fact had since been confirmed by the re-survey of the island. At the same time he admitted that the Colwell Bay Bed contains a more marine fauna than the Headon Hill Bed and thought that geologists owe Professor Judd a debt of gratitude for drawing attention to the difficulties of these sections, and by his action stirring up others to try and unravel the problems which he had set before them. The party then proceeded to Totland Bay, where they had tea at Mr. Gilmer's refreshment rooms and returned to Sandown by the 7 o'clock train.

On *Monday, April 15th*, the party left Sandown by train at 8.27 for Yarmouth, Mr. Herries again acting as director, assisted by Mr. Colenutt, who had again joined the party at Newport. They walked along the foreshore in an easterly direction, crossing over the Bembridge Marls, which unfortunately were almost covered by the rising tide. These beds, as the Director explained, lie in a syncline, passing under the Hamstead Beds and reappearing from under them some three miles to the N.E. Arrived at the "Black Band," a bed of carbonaceous clays, forming the base of the Hamstead Series, the party divided into two bodies, the smaller of which, leaving the shore at Bouldnor, followed Mr. Herries in a rapid walk to the top of Hamstead Hill. Here they examined several sections at the top of the Cliff, and, though unsuccessful in finding the bed of *Ostrea callifera*, which should occur immediately under the gravel, they found good exposures of the marine *Corbula*-beds, and the *Cerithium plicatum* beds below. *Corbula pisum*, *C. vectensis*, *Cerithium plicatum*, *Cyrena semistriata*, etc., were found in great abundance, and the party descended the slopes of the cliff, which

*Quart. Journ. Geol. Soc., vol. xxxvii, p. 85.

were fortunately tolerably dry and hard, to the shore. Here they examined a good exposure of the "White Band" in the cliff and collected the characteristic fossils, *Cerithium inornatum*, *Melania fasciata*, *Unio Gibbsii*, seeds, and fish remains. Returning, they met the remainder of the party, who, under the able guidance of Mr. Colenutt, had followed the shore at a more leisurely pace, and had collected bones and portions of the carapace of the turtles *Emys* and *Trionyx*, and bones and teeth of some of the mammals and crocodiles that lived in the late Oligocene period, among others *Hyopotamus bovinus*. Mr. Colenutt pointed out the conspicuous "White Band," where it crosses the foreshore, being forced up into a nearly vertical position by the heavy slips from above. This bed consists of alternations of green clays with white shelly marls, and is from 4 to 6 feet thick. The party then returned by the shore to Yarmouth with some difficulty owing to the rising tide.

After luncheon, Mr. Colenutt took the opportunity of exhibiting a number of specimens of *Clupea Vectensis*, the small fish from the Osborne Beds of King's Quay near Ryde, of which he was the discoverer and on which he wrote a paper in the *Geological Magazine*, Dec. 3, vol. v (1888), p. 358. The fish has been more particularly described by Mr. E. T. Newton (*Quart. Journ. Geol. Soc.*, vol. xlv, p. 112). Mr. Colenutt kindly distributed the specimens he had brought with him as well as some *Chara* seeds and other fossils washed out of the "White Band," amongst the members. A start was then made over the bridge and along the military road for Colwell Bay, a halt being called at Cliff End, where there is a good roadside section of the Bembridge Limestone. Scarcely a mile from Sconce Point, the limestone here contains the same fossils as were formerly found at that celebrated locality, and in a short time the more ardent collectors had obtained several specimens of *Bulimus* and *Achatina*, as well as the large *Helix globosus*. The Director pointed out the mottled clays of the Osborne Beds below, on the other side of the road, and the party then proceeded to Linstone Chine, where they descended into Colwell Bay. The Director took them back a little way towards Cliff End, in order to point out an exposure of the attenuated representative of the Upper Headon Limestone, here only 16 inches thick, as against 27 feet at Headon Hill. Just below is the zone of *Cerithium trizonatum*, from which a number of specimens of that fossil were collected. Some curious contortions in the strata were also pointed out (see *Proc. Geol. Assoc.*, vol. xii, p. 150, fig. 1). The party then proceeded leisurely along the shore southwards, collecting from the marine Middle Headon, which is particularly rich near Bramble Chine. The members were rewarded with *Cytherea incrassata*, *Buccinum labiatum*, *Neritina concava*, *Nerita aperta*, *Murex sexdentatus*, *Ostrea velata*, *Corbula cuspidata*, *Lucina inflata*, *Natica*, etc., etc.

The great Oyster Bank in the middle of the bay was pointed out, and How Ledge, a reef running out to sea, formed by the highest limestone of the Lower Headon. In this limestone is a series of small reversed faults, which were pointed out by the Director (see *Survey Memoir*, p. 242). Rounding Warden Point, where Warden Ledge, another reef, formed of a hard concretionary sandstone, runs out, the section (Fig. 5) was seen, and the lower limestones were searched for *Chara* seeds, a few of which were found. The party then went up at the Totland Bay Hotel, and again had tea at Mr. Gilmer's refreshment rooms. On the way to the station Mr. Leighton took them into the Brickyards at School Green, where another good section of Middle Headon was seen, after which the party returned to Sandown by the 7 o'clock train.

On *Tuesday, April 16th*, after forwarding their baggage to Ryde, the party took the 10.45 train to St. Helens. With Mr. Monckton as director, they walked to old St. Helens church tower, which stands on the shore on the North side of Brading Harbour. Here the Bembridge limestone is at the sea-level, and rises up into the cliff to the north, and the Director reminded the members that on Friday they had crossed over the great anticline of the Isle of Wight, and had entered on the syncline to the north. They were now almost on the centre of that syncline, and in the course of the day, between St. Helens and Ryde, they would see another small anticline, the Bembridge limestone now at their feet, and running out to sea, gradually rising and allowing the underlying Osborne Beds to form the cliff under Priory Woods and at Sea View. No Hamstead beds were to be seen in the cliff at St. Helens, but it was possible that there was an outlier on the top of the hill. The Bembridge Marls were well shown, and just above the Oyster bed at their base there is a band with some shells of marine origin, which, according to Edward Forbes, have not been noticed elsewhere. The members proceeded to search for these fossils, and specimens of *Arca Websteri* were found, as well as *Mytilus affinis*, *Natica*, *Melania muricata*, *Ostrea Vectensis*, etc. The Bembridge limestone was also found to be, as usual, full of fossils. The party then proceeded northwards to Sea View, and examined the Osborne Beds, which form a small local anticline. Here the usual mottled clays have been replaced by a series of sands (St. Helens Sands), which are underlain by a series of limestones, grits, and sandstones (Nettlestone Grits). The grits are particularly conspicuous at Horestone Point, where they are full of flint pebbles; they are brought up there by a small fault (*Survey Memoir*, p. 157). From Sea View the party proceeded to Ryde by the sea-wall, and, crossing over to the mainland by the 4 o'clock boat, the members dispersed to their various destinations.

The Directors wish to take this opportunity of thanking Mr.

G. W. Colenutt, of Ryde, Mr. H. St. Barbe, of Lymington, and Mr. J. Duce, for much valuable assistance both before and during the excursion, and also Mr. Clement Reid, of H.M. Geological Survey, who, by his practical advice based on intimate knowledge of the beds, and by his many useful suggestions, materially aided them in preparing the details of a somewhat difficult programme. It only remains to add that the weather throughout the excursion was perfect.

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EXCURSION TO CHARLTON (KENT).

SATURDAY, 20TH APRIL, 1895.

Director:—T. V. HOLMES, F.G.S.

(*Report by the* DIRECTOR.)

On arrival at Charlton, the party at once proceeded to the great pit a few yards east of the Railway Station which has been the scene of so many excursions of the Association, the earliest having taken place in August, 1860. This pit, from which so many thousands of tons of Chalk and Thanet Sand have been removed, has now ceased to be worked; the line of railway thence to the river has disappeared; and the entrance is now not from the Woolwich Road but by a road marked *private*, which turns eastward from a point about 50 yards south of the Charlton Railway Station We visited it by kind permission of Mr. Ellis, the present proprietor.

On entering the pit, the Director explained the reason of the existence of the Lower Tertiary escarpment, in which this pit is one of many sections. The Chalk (he remarked) to which the overlying

One of the party was fortunate enough to find a fine lump of allophane (a hydro-silicate of alumina) in the position indicated.

It was not easy to ascend higher in this pit than the lower beds of the Thanet Sand, so after spending some time in collecting Upper Chalk fossils, the party departed in an easterly direction and entered another pit a few yards away, in the side of the hill which stands out like a promontory between the Charlton pit just visited and the new recreation ground for Woolwich known as Maryon Park. In the western flank of this hill, which juts out to the north, the uppermost beds of the Chalk and the Thanet Sand are well shown, and the Woolwich Beds and Blackheath Pebble Beds are almost equally well exhibited on the eastern flank, which looks upon Maryon Park. On the top of the hill is the fragment of an old camp—not Roman, Mr. Spurrell remarked, but British, though called Roman on the new ordnance map. The greater portion once occupied the hill which stood where, owing to the removal of the Chalk and Thanet Sand, there is now a hollow transformed into a recreation ground. From the top of the hill we had a magnificent view. Southward it was bounded by Shooter's Hill and the well-wooded land about Old Charlton. On the north-east appeared the Essex Hills at Havering-atte-Bower and around Brentwood, and still further eastward arose the outlier of Bagshot Sand capped by gravel, known as Langdon or Laindon Hill.

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EXCURSION TO BRIGSTOCK AND GEDDINGTON.

SATURDAY, APRIL 27TH, 1895.

Directors: BEEBY THOMPSON, F.C.S., F.G.S., and W. D. CRICK, F.G.S.

(*Report by* BEEBY THOMPSON.)

The members arrived at Corby (Weldon Station) about 11 o'clock, and proceeded to examine a section of Upper Lias Clay, newly opened by the Weldon and Corby Brick Company. Owing to the recent heavy rains very little could be done here, but a few fossils were obtained, including *Ammonites bifrons*, *Myacites donaciforme*, *Inoceramus*, etc. The clay is micaceous, and has a capping of Northampton Sand, though the junction between the two formations is most irregular owing to slipping.

BRIGSTOCK SECTION—LINCOLNSHIRE OOLITE AND DRIFT.

(Showing positions in which Land and Fresh-water shells were found by Mr. Albert Wallis.)

a, *a*. Soil to brown drift, with few stones and boulders.
b, *b*. Brown clayey drift, with many boulders (oolitic and flint and chalk predominating), Boulder-clay.
c, *c*. Sandy clay in bands without boulders; probably disturbed Upper Estuarine clay.
d. Distorted Oolite and Boulder-clay, much confused.
e. Redistributed Oolite in small stratified beds, with flint and oolitic water-worn stones and recent shells + often distorted.
f. Disintegrated Oolite with large lumps of hard oolitic rock.
g. Floor of quarry.

(Scale: 6 feet to the inch. Length of Section 36 feet.)

Within a hundred yards of the above is a long working face of the ironstone beds of the Northampton Sand; the ironstone being capped by the white sands of the Lower Estuarine beds, with abundant vertical plant markings, and above this again some ruddy sands and rubbly beds (Lincolnshire Oolite ?). Very little time, however, could be spared here.

A walk of about four miles brought the party to Brigstock Mill. The chief object of the excursion was to examine a section of Lincolnshire Oolite at this place, in which land and freshwater shells of species now living had been found by Mr. Albert Wallis, of Brigstock. (The description of section, and discussion, appears later on in this Report.)

The next section visited was one on the east side of Stanion, Lord Cardigan's pits, where the Lincolnshire Oolite was formerly extensively quarried.

The visit to Little Oakley was omitted for lack of time, sc that the next stoppage was made at Geddington, to examine the "Eleanor Cross" there. A short stay was made at a quarry in the Lincolnshire Oolite just outside Geddington, on the road to Kettering, and a number of characteristic fossils were obtained.

Kettering Station was reached in time for the 4.30 return train to London.

A paper has already appeared in *The Geological Magazine* for May, describing the Brigstock Mill section, and reprints in advance were, through the courtesy of the editor, Dr. Henry Woodward, available for members on the day of the excursion. The following particulars are, to some extent, a repetition of the contents of that paper:

DESCRIPTION OF BRIGSTOCK SECTION.

By Beeby Thompson.

(*Compare with Plate and Description by* Mr. Albert Wallis.)

1. Soil, Boulder Clay, and Gravel, not very distinctly separable the one from the other, or from the bed next below, but all three containing pebbles, fragments of flint, and chalk. Thickness very variable.

2. Confused layer; Boulder Clay, gravel, fine sand, and shelly oolite very much mixed up, and the junction with the purer Oolitic beds below very irregular. Thickness may reach four feet in places.

3. Disturbed Oolite, consisting largely of small shells or fragments of such, a good proportion being gasteropods, mostly water-worn or encrusted with carbonate of lime, so that all trace of finer ornamentation is lost, many only internal casts. In places it takes the character of a fine, calcareous sand.

It also contains quartzite pebbles and flints, etc., irregularly and sparsely distributed, and is the part in which the land and freshwater shells were found.

4. Oolite similar to No. 3, except that it is harder, more compact, and contains nothing exceptional. Nodular or hummocky masses of this bed rise in places into the softer zone above.

The combined thickness of parts 3 and 4 of the section is as variable as the Clay and Soil, etc., above them, but in the deepest part reaches 9 or 10 feet.

Here and there in the section "gullies" or "pipes" occur, filled in with Boulder Clay and stones; they begin in the confused layer, No. 2, and mostly reach below the present working (see plate).

The land and freshwater shells found in the shelly Oolite, No. 3, included the following species:

Succinea putris.
Cochlicopa lubrica.
Helix pulchella.
Helix nemoralis (or *arbustorum*).
Pupa marginata.
Pisidium pusillum.

Some of the specimens were rather poor, and all thin and fragile; but there can be no doubt as to the identification, for the least satisfactory ones have passed through the hands of both Mr. Lionel E. Adams, B.A., of Northampton, and Mr. J. W. Taylor, of Leeds.

The following additional particulars with regard to the section are important in connection with any theory attempting to explain the occurrence of the above-named shells in the Oolitic beds:

(*a*) The shells were found *only* in that part of the section numbered 3, but at several places and at variable depths (see plate).

(*b*) The best preserved shells were imbedded in a clay matrix when found.

(*c*) Minute fragments of shell can almost always be found by picking out portions of the soft sandy layers of No. 3, indicating a destruction of many specimens compared with the few preserved.

(*d*) None of the shells, even in a fragmentary condition, have been found in, or in any way connected with, the "pipes," although these have been carefully searched.

(*e*) The whole of the Oolitic matter as far down as the harder and hummocky masses of No. 4, has evidently been disturbed and re-arranged, for it is quite easy to find in it flints and pebbles (Bunter ?) from the "drift," as far down as, but no farther than, the shells have been found.

The explanation given in *The Geological Magazine* for May, by the author of this Report, was about as follows: The land and freshwater shells were embedded in the clayey soil or sub-soil of some district near, in pre-glacial times, and on the first advance of the ice sheet they were moved *en masse* with portions of the underlying rock, and constituted a part of the earliest Boulder Clay of the district, of which scarcely a trace in its original form now remains. During the succeeding so-called inter-glacial period, the rapid melting of the ice produced strong currents of water which washed away most of the argillaceous matter of this early Boulder Clay, and even bared, and, in places where the material was not very coherent, disturbed the underlying rock, re-depositing its material along with the coarser material of the Boulder Clay itself. During all this, some of the masses of clay escaped total destruction, and, greatly diminished in size, got buried with the drift and disturbed calcareous beds, and with the clay the shells in it; shells not so protected during the inter-glacial period were naturally broken into fragments at the same time that the fossils in the Oolitic beds were being water-worn (see No. 3 of Section and *c*).

The upper part of the section (1), represents the upper Boulder Clay, so very common in Northamptonshire, and the disturbance connected with the advance of the second ice sheet seems to have extended downward to the base of No. 2 of the section.

A discussion took place at the Brigstock section itself after examining the shells that had been found and the positions in which they were found. A brief summary of the objections then and afterwards urged against the theory stated above is given below, together with the replies thereto by the author of the theory:

1. One member insisted that the shells could not be as old as the theory involved because no shells of the species named had been recorded from pre glacial beds; also they were very mutable forms, and so it was improbable they could be so old.

    This objection falls to the ground, because the species recorded, excepting *Helix nemoralis* and *Pisidium pusillum*, are found in the Crag beds, and these two occur in the Forest Bed, and all have been recorded from the Pleistocene Gravels. There is, therefore, no *à priori* reason why they should not occur beneath the Boulder Clay.

2. Other members were not satisfied that the material described as Boulder Clay was such.

    So far as I can see, the only alternative to calling it *Boulder Clay* is to describe it as *Clay containing Boulders*; but since the boulders are of just the same character as are to be met with in unquestioned Boulder Clay of the district, and the district is mostly covered with Boulder Clay, so much so indeed that it is the rule to find it and the exception not to, and that no specific reason has been urged why

this should be regarded as abnormal, I do not yet consider it necessary to modify the original description.

In connection with the subject I would refer those who are doubtful about the Boulder Clay to the perfectly independent description of the section appended to the plate, by Mr. Albert Wallis, a resident of Brigstock; also to pages 149 and 150, and the first paragraph of page 191 of Judd's *Geology of Rutland.** I quote the most pertinent paragraph on page 149: "Between the Harper and Willow brooks the Jurassic strata are again wholly concealed by the thick masses of Boulder Clay. On the outer escarpment, however, at Stoke Albany, Wilbarston, Cottingham, and Rockingham, the beds of the Lincolnshire Oolite are exposed by denudation below the great superficial accumulations. They are also equally well seen along the sides of the valleys formed by the Willow Brook and its tributaries, as about Corby, Weldon, Dene, Bulwick, Blatherwycke, etc."

3. A suggestion was made that, supposing the material described as "Boulder Clay" or "Drift" were such, it might not be *in situ*, but have slipped or been washed down from higher ground near.

I cannot admit this as at all probable, for the situation of the Brigstock section is such that the ground dips away from it in three directions, and in the only direction from which slipped material could have come the ground has a very gentle inclination, a gradient *much less* than the angle of repose of any clay with which I am acquainted.

EXCURSION TO HANWELL, DAWLEY, AND WEST DRAYTON.

SATURDAY, 4TH MAY, 1895.

Director: J. ALLEN BROWN, F.G.S.

(*Report by the* DIRECTOR.)

This excursion was arranged to facilitate the examination of the two forms of river Drift and other deposits referred to in the paper read by the Director at the meeting of the Association the previous evening.

* "The Geology of Rutland and parts of Lincoln, Leicester, Northampton, Huntingdon and Cambridge." By John W. Judd, F.G.S. 1875. *Memoirs of the Geological Survey.*

Leaving Hanwell Station at 2.28 p.m., the members, of whom there was a good attendance, proceeded to Mr. Gibson's pit, near the iron bridge crossing the Uxbridge Road, in which were seen fine sections of contorted, as well as of unstratified, deposits above horizontally bedded drift. The section was 20 feet in depth, and unstratified gravel, with enclosures of bluish clay, sand, etc., with a huge furrow reaching from the top to the base of the excavation, were well exposed; the stratified gravel being very noticeable at the northern side.

The furrow is within six or eight feet of a similar deep, infilled furrow, of which a section was exhibited at the meeting on the 3rd inst., and the gravel in the space between them was seen to be contorted and squeezed into arch-like forms. The remains of other like furrows and contorted deposits in the pit, and long and deep sections of unstratified drift throughout the excavation, were pointed out.

Returning to the Hanwell Station, the members took the train to Hayes, and from there walked along the canal to Dawley, where, in Mr. Odell's pits, the implementiferous lower bed of stratified gravel was surmounted by a thick deposit, of irregular form, of sharp, white sand, and above it unstratified gravel and clay which filled a long, shallower depression, and extended on both sides of it. Passing on to Mr. Maynard's extensive pits there, a very fine exposure of unstratified drift, with enclosures of sand and clay, about five or six feet in thickness, with brick earth above it, was seen to rest on well-defined stratified gravel, and was shown to extend along the whole length of the excavation, inclining upwards towards the surface to the west. A photograph of the section was taken by one of the members. This section, like the others, was held by the Director to confirm his views, *i.e.*, that there are two different kinds of gravels in the high level river drift, the upper one being formed by combined river and ice agency (fluvio-glacial). Returning to the canal, Mr. Pipkin's pit was visited, where the very remarkable wave-like forms of chalky matter, clay, and stones were seen overlying contorted sandy deposits and unstratified gravel, and underlying dense undisturbed brown brick earth. The Director pointed out that no disturbance had ever taken place in the upper brick earth since it had been deposited.

Messrs. Eastwood's large pits at West Drayton were afterwards reached, and some fine sections of the unstratified deposits of gravel, sand, and clay were noticed. The section only reached to the upper part of the bedded implementiferous gravel beneath. A photograph was taken of the section by one of the members.

The members were able to return to town by the 6.29 p.m. train, after returning thanks to the Director for causing some of the sections to be cleaned of talus for the occasion.

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EXCURSION TO CHILWORTH.

SATURDAY, 11TH MAY, 1895.

Director: J. W. GREGORY, D.Sc., F.G.S.

(*Report by the* DIRECTOR.)

This excursion was supplementary to one made last year (*Proc. Geol. Assoc.*, vol. xiii, p. 377). Then it was seen that the Lower Greensand to the east of Guildford consists of the following series of beds:

5. Upper Ferruginous Sands.
4. A calcareous grit (Bargate Stone) associated with a series of Pebble Beds.
3. Lower Ferruginous Sands.
2. Passage Loams.
1. Atherfield Clay.

The outcrop of the Bargate Stone was then followed, and this bed was seen to split up into two, as followed to the east, and to have pebble beds both above and below. On that excursion, however, no chert was seen *in situ*, and the object of the present excursion was to show the relation of the cherts to the rest of the series. The cherts do not occur on the northern outcrop of the Lower Greensand, but are extensively developed to the south. The Bargate stone, on the other hand, occurs to the north, but not to the south, so that the exact superposition cannot be seen. The district, however, around Woodhill enables their relations to be determined with tolerable certainty.

The party assembled at Chilworth Station, and walked thence southward to Blackheath (Fig. 1). Here the Folkestone Sands form the moorland on the heath, and from it a good view of the surrounding country can be obtained. From this point a long, gradual slope led down to a stream, which had cut through the Lower Ferruginous Sands and Loams to the surface of the Atherfield Clay. A long slope leads up to the fir woods of Sandhurst Copse. On the way some road-side sections showed the Lower Ferruginous Sands; then some pebble beds, and some

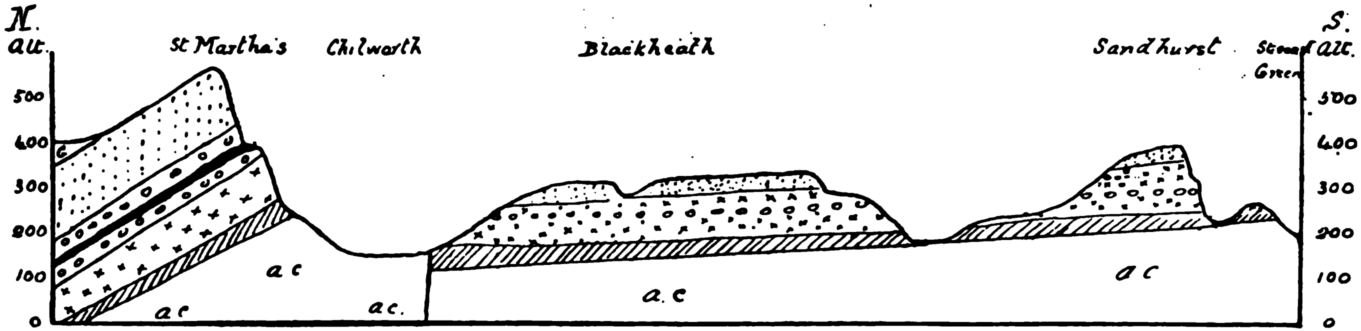

FIG. 1.—SECTION FROM ST. MARTHA'S ACROSS BLACKHEATH TO STROUD FARM.—*J. W. Gregory.*

Vertical Scale, 1 inch=400 feet. *Horizontal Scale, 1 inch=2 miles.*

For Index of Shading see Fig. 2. The black band to the left is Bargate; and *a c* includes Atherfield and Weald Clays.

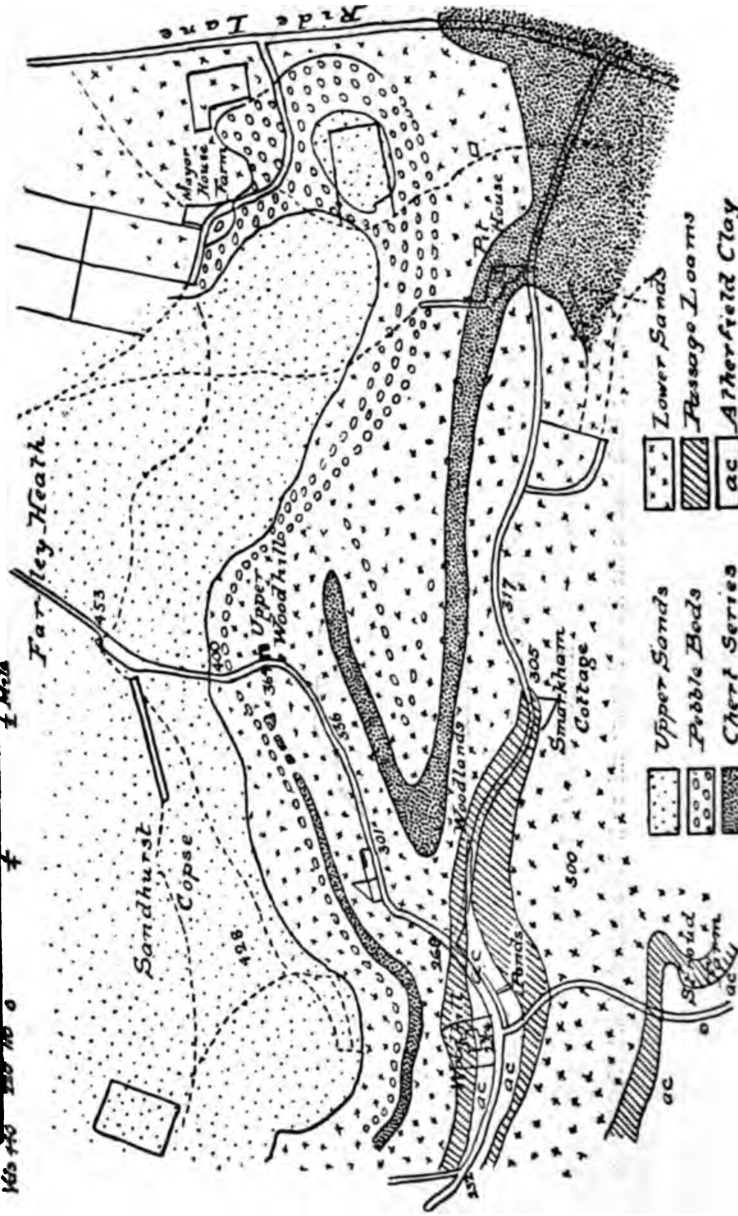

FIG. 2.—MAP OF THE NEIGHBOURHOOD OF WOODHILL, NEAR CHILWORTH.—J. W. Gregory.

hard, nodular, but unfossiliferous grits, which are approximately on the horizon of the Bargate Stone to the north. A little higher up are the soft sands of the Upper Ferruginous Sands, which form the whole of the Sandhurst Ridge. A steep descent then led to Woodhill, where some ponds occur on the Atherfield Clay. The party then followed along a narrow, dry valley; the summit of the steep bank to the north is capped by a thin bed of chert, which can be traced by the occurrence of nodules along the brow of the ridge. Above this occur pebble beds with, in places, blocks of a calcareous grit. In the winter, when the fields are bare, the cherts and pebble beds can be clearly traced all along a line (Map, Fig. 2) past Upper Woodhill, till the cherts thin out to the west. They do not occur in the line of section of Fig. 12. To the east they thicken, and past Pit House they can be clearly seen on the road and on the banks. Thence they further thicken, and expand into the great chert plateau of Winterfold Heath.

From the cherts at Pit House the party struck across the fields, over some slopes of Lower Ferruginous Sands, to the outcrop of the Pebble Beds, which were well seen on the surface of the ground, and in a couple of sections near Mayor House Farm. After passing these, the Upper Ferruginous Sands were reached on Farley Heath, and these were crossed for some distance back to Blackheath, above Chilworth.

The geology of the county was not as clearly seen as it might have been had the excursion been less hurried, and the fields bare of crops. But the following points were clearly determined:

(1) The disappearance of the fossiliferous Bargate Stone to the south.

(2) The appearance of the cherts to the south of the Lower Greensand area.

(3) The fact that the cherts occur in the Lower Ferruginous Sands and rather toward the upper part of that bed.

(4) The fact that the cherts occur below the level of the Pebble Beds, and do not, therefore, represent the southern continuation of the Bargate Stone.

(5) The Pebble Beds themselves occur to the south in approximately the same position as in the Chilworth District, but they are thinner, and appear to be slighly lower in horizon.

The full sequence is, therefore, as follows:

5. Upper Ferruginous Sands.
4. Pebble Beds and Bargate Stone.
3. Lower Ferruginous Sands and Chert Beds.
2. Passage Loams.
1. Atherfield Clay.

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EXCURSION TO BETCHWORTH AND HEADLEY.

SATURDAY, 18TH MAY, 1895.

Directors:—H. W. MONCKTON, F.L.S., F.G.S., and W. P. D. STEBBING, F.G.S.

(*Report by the* DIRECTORS.)

The party assembled at Cannon Street Station, and travelled by the 1.35 p.m. train to Betchworth Station on the South Eastern Railway. On arrival the party ascended the chalk downs, and walked across Headley Heath to Headley Church, which stands on one of a group of Eocene outliers on the chalk, as is shown in the diagrammatic section (p. 125).

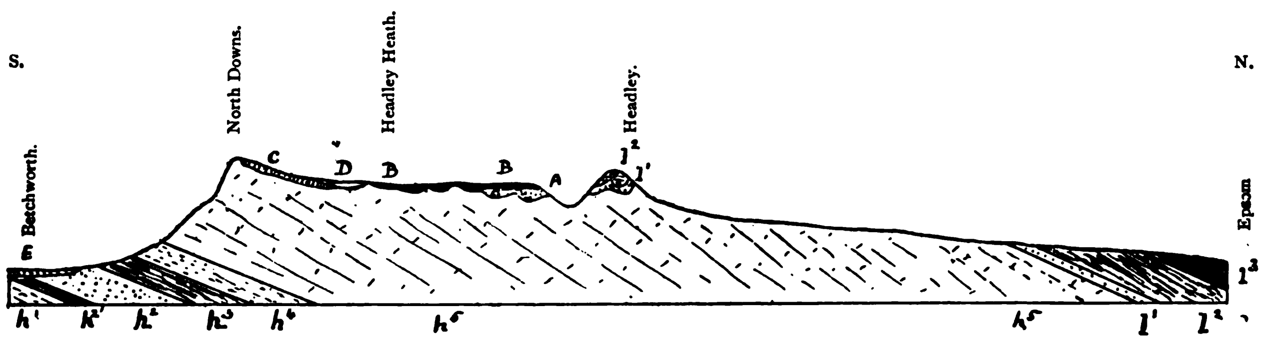
On the north side of the outlier, Mr. Stebbing pointed out a small exposure in the Thanet Sand in a sandpit, and at a rather higher level at the roadside he had discovered the oyster bed of the Woolwich and Reading Series. Specimens of the oysters—*Ostrea Bellovacina*—were obtained by such of the party as cared for them. The oyster bed is overlain by mottled clay, and according to Prof. Prestwich,* there is a thick pebble bed at the top of the hill. This is no doubt in what is now Nower Wood, and clearly the pebbles which are very abundant in the gravel at Tot Hill, are derived from it.

The party next proceeded to a sand and gravel pit at Tot Hill, where Mr. Monckton made the following remarks:

"The height of the group of Eocene outliers at Headley is 600 feet above the sea—that is rather more than 100 feet below the crest of the North Downs at this part of their range, the Betchworth Hills and Colley Hill, above Reigate, being 700 feet above sea-level. The occurrence of Eocene beds at this low level is partly due to the fact that the strata here dip to the north, and consequently the outliers rest on the dip slope of the chalk; but I am inclined to think that they also rest very unconformably on it, an unconformity not due to original unconformable deposition, but to the subsequent subterranean decay of the chalk

* *Quart. Journ. Geol. Soc.*, vol. x (1854), p. 97.

SECTION FROM EPSOM TO BETCHWORTH.—*H. W. Monckton.*



l^3. London Clay.
l^2. Reading Beds.
l^1. Thanet Sand.
h^5. Chalk.
h^4. Upper Greensand.

h^3. Gault.
h^2. Lower Greensand Sandy Beds.
$h^{2'}$. Atherfield Clay.
h^1. Weald Clay.

E Gravel and Brick-earth of the River Mole.
D Brick-earth or Loam on Clay with Flints.
C Clay with Flints.
B Gravel.
A Sand.

The horizontal scale is 1 inch to the mile. The vertical scale is six times the horizontal.

by which the Eocene strata have been let down,* and I believe that they now lie on the chalk in the irregular manner which I have indicated on the diagrammatic section in the programme where the unconformity is much exaggerated.

"The Eocene outliers consist of Thanet Sand and Reading Beds, and a vast interval must have elapsed between their deposition and that of the next formation at this place. The next deposits are the sand bed A with the gravel B which overlies it, and they like the Eocene beds have in places been much disturbed by the decay of the chalk beneath them. This is more especially the case at Tot Hill, where a mass of the gravel B may be seen resting against the sand A instead of lying on top of it, and the sand A extends nearly to the bottom of a little side valley in the chalk far below the level of the Eocene outlier—a position in which I do not believe it was originally deposited. In places it looks as if the strata had sunk down into a very large swallow-hole,† and I think this may well have been the case.

"On the chalk downs near Chipstead, 4½ miles east of Headley, there is a patch of sand very like the bed A of our section, and in 1858 Prof. Prestwich suggested that it might be of the same age as the Lenham Beds,‡ and it is therefore possible that the sand A of Headley—the patch of sand at Chipstead, and also one at Netley Heath—may belong to the early Pliocene.§ In any case I feel sure that they are more recent than the Eocene Period.

"Though the gravel B has in places been subject to slipping and letting down, it forms as a whole a fairly flat plain, the highest part of which is some 630 feet above the sea. The gravel consists mainly of flints from the chalk—often large, as much as a foot in length—sometimes hardly at all water-worn, but usually a good deal rolled. There is also a large proportion of flint pebbles from the Eocene Beds and some chert and ironstone from the Lower Greensand.

"The presence of this last ingredient in fair abundance shows that the gravel is derived from the south, and as it is now bounded on the south by the clay-with-flints C, which runs along the crest of the downs, the gravel B must be older than at least the greater part of the clay-with-flints C. Next, a bed of loam or brick-earth D rests on the clay-with-flints, and finally the gravel of the River Mole E is obviously newer than the beds A, B, C, D. We have thus established the order of succession of the beds shown in the section in the programme."

After an examination of the pits the party proceeded to

* Compare Topley, *Geol. of the Weald* (1875), p. 230, Fig. 45.
† Evidence of this was pointed out on the spot.
‡ *Quart. Journ. Geol. Soc.*, vol. xiv (1858), p. 331, note.
§ See Whitaker, *Mem. Geol. Survey*, vol. iv (1872), p. 339.

Heath House, where Mr. and Mrs. Stebbing entertained them at tea. Afterwards a collection of Chalk fossils from Betchworth, belonging to Mr. W. P. D. Stebbing, was inspected, and the party again crossed Headley Heath to Pebble Coombe, near which are some workings in clay-with-flints, which were inspected, and Mr. Monckton continued his remarks as follows:

"It will have been observed as we crossed Headley Heath that, in spite of subterranean erosion and decay, the gravel B is in places fairly flat, and where similar gravel rests upon non-calcareous beds, as in the case of the hills round Aldershot, for example, the flatness of the surface is very marked.

"These flat expanses of gravel do not, however, only occur at the tops of hills—there are plenty of examples at all sorts of levels down to the gravel-covered flats on both sides of the Thames, near London, which are but little elevated above the sea.

"Upper Hale, Aldershot, is one of the highest of these gravel-flats in this part of England, being 600 feet above the sea, and it is noticeable that, in places, it has what seems to be the remains of a covering of brick-earth, just as is the case with the low-level Thames gravels.

"Now I am quite unable to conceive any method by which all these gravel-flats, ranging from sea-level to 600 feet above, could have been deposited simultaneously—neither the sea, nor a lake, nor rivers, nor a flood, nor ice, could at one and the same time, have laid down these gravels where we now find them.

"Clearly long periods must have elapsed between the deposition of the different sheets of gravel.

"If, however, we accept Prof. Prestwich's view that some of the gravels I have mentioned, and which he includes in his Southern Drift, are pre-glacial in age, and if, as I think is clear, we have a continuous succession down to the lowest gravels of the Thames Valley, then we need feel no trouble as to length of time—the Glacial Period is long enough for us.

"After a careful consideration of the views of various authors and a lengthy examination of the gravels themselves, I have adopted the opinion that the gravels of these flats have been formed by river action—of course assisted by ice and snow during the glacial period. My views on this point will be found in the *Quarterly Journal* of the Geological Society for 1892,* and I am pleased to find myself on the same side as Mr. Hudleston, at any rate as regards the hill or plateau gravels.†

"In 1892 Mr. Clement Reid brought forward a new theory as to the origin of the Thames Valley gravels,‡ contending that they

* *Quart. Journ. Geol. Soc.*, vol. xlviii (1892), p. 45.
† *Quart. Journ. Geol. Soc.*, vol. xlix (1893), *Proc.*, p. 76.
‡ *Quart. Journ. Geol. Soc.*, vol. xlviii (1892), p. 360.

are not river-gravels, but frozen-soil gravels laid down on plains sloping gently to the River Thames. This view seems to suppose that the Thames Valley was formed without gravels, and that the gravels then 'as one sheet' 'belonging to a single period' were introduced. It is scarcely fair, however, to criticise this theory, as it has not yet been worked out by the author in detail, but perhaps I may say that though I think it possible, and even probable, that there are frozen-soil gravels in the Thames Valley, I think at the same time that the greater part of the gravels are true river-gravels, though no doubt their formation was largely due to glacial conditions.

"As to the clay-with-flints, I think we may safely adopt Mr. Whitaker's opinion that it results from the decomposition of the chalk, and that the brick-earth which overlies it is mainly a loamy wash from Tertiary beds. If this be so, the clay-with-flints has been in process of formation simultaneously with the gravels ever since this area rose for the last time above the surface of the sea." *

The party then descended Pebble Coombe, and the next halt was made at the pit in the Upper Greensand, on the east side of the road, a little north of Betchworth Station. The section is very similar to that described in Topley's *Memoir on the Weald*, p. 154, and this actual pit, which extends for about 200 yards under the hill, was visited by the Association on May 24th, 1884, on which occasion a considerable number of fossils were obtained.†

After a short halt in this locality, the party proceeded to Betchworth Station and returned to London by the 7.27 train.

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* Whitaker, *Geology of London*, 1889, vol. i. p. 282.
† *Record of Excursions*, p. 87.

CH OF THE GEOLOGY OF CO. ANTRIM.

ALEX. McHENRY M.R.I.A., *of the Geological Survey of Ireland.*

Read 5th July, 1895.)

County Antrim is particularly interesting to the Irish eologist, as within its bounds are to be found representa- almost every geological formation that occurs throughout

ginning with the older formations, we have, in the northern of the county, in the neighbourhoods of Cushendall, dun, and Ballycastle, the foliated crystalline rocks, the age ch is at present unknown, though they probably belong to d not later than the Ordovician; while immediately on the ast of the county, in County Down, the Ordovician and strata occur in great force.

Cushendall and Cushendun there is a considerable extent wer Old Red Sandstone rocks, consisting of massive conglomerate, sandstone, and shale.

the extreme north of the county, at Ballycastle, and ing round Fair Head beneath the dolerite, to Murlough re to be found representatives of the Lower Carboniferous ion.

e Permian rocks do not appear at the surface in County , but a few miles to the north-east of Belfast, on the south f. Belfast Lough, they occur in close proximity to the Lower niferous and Triassic rocks (New Red Sandstone).

e Trias, consisting of the Bunter and Keuper divisions, in considerable extent throughout the county, especially in thern portion of it, where it attains a maximum thickness r 1,000 feet. In the north of the county, however, it les down to but a few feet, as at Torr Head and gh Bay.

e Rhætic Beds occur generally in the south and south-east, atest thickness being in the neighbourhood of Larne.

s is well represented at several places, notably at Larne and Magee, and in the north at White Park Bay and Portrush.

etaceous rocks, consisting of Upper Greensand and Upper appear from beneath the basalt plateau almost continuously the whole county on its north, east, and southern boundaries, tends into County Derry on the west, its general position at the base of the basaltic escarpment.

pping all the other rock-formations, and almost completely ng the whole county, is the great plateau of Tertiary Basalt, ting two well-defined and distinctly separate periods of ic activity. The Period of rest is defined by the remark- nd important deposit of the Pisolitic Iron-ore zone, and its iated plant-, ash-, bauxite-, and bole-beds.

Boulder Clay is very extensively and generally distributed over the whole country, and is to be found in considerable thickness even on hills over 1,000 feet high.

We have also vast tracts of peat-bog, which not only spread over large areas of low ground, but also extend over the highest hill-tops in thick coatings.

Lastly, we have many examples of raised beaches, sea caves, sea stacks, and old river terraces at Kilroot, Larne, Glenariff, Cushendall, and elsewhere round the coast, the river terraces being particularly well marked in the Carey River valley, east of Ballycastle.

The accompanying map (Plate VI.), on a scale of four miles to an inch, reduced from the Geological Survey Map, will serve as a general guide to the formations.

Metamorphic Rocks.

These rocks are confined, as before-mentioned, to the north-east portion of the county. They consist of coarse and fine-grained felspathic and quartzose pebbly schistose grits, green chloritic, and grey micaceous schists with bands of quartzose schist, and grey crystalline limestones. Associated with these rocks are dark green epidiorites, and grey and pinkish granulites, which were evidently intruded as igneous veins and large masses previous to the metamorphism of the sediments by earth movements and crushing. The epidiorites are in great abundance at Torr Head, where they are tangled and sheared up with the crystalline limestones in every conceivable manner. Fine sections are to be seen under the coastguard watch-house.

Just north of Cushendun these hornblendic schists (epidiorites) occur also in force, exhibiting beautiful banding and foliation, along with the sedimentary schist rocks into which they have been intruded.

Grey and pink banded and foliated felspathic granulites are also very abundant in the schists. In the neighbourhood of Cushendun good sections of them can be seen at several places along the mail-car road to Ballycastle, and close to the old road leading to Torr Head.

An intrusive red microgranite mass occurs in the schists to the north-west of Cushendun, smaller bosses, dykes, and veins of the same rock being very common between the main granitic mass and Torr Head. At many places along the public road the relations of these rocks can be readily seen and studied, as well as on the sea-cliff sections between Cushendun and Murlough Bay. Staurolite and tourmaline occur in the schists close to the main road, about half-way between Cushendall and Ballycastle; also in the vicinity of Ballycastle on the north slope of Knocklayd Mountain.

Vein quartz is abundant throughout, especially in Glenshesk

Valley, south-east of Ballycastle, where a thin vein of jade was also found.

ORDOVICIAN AND SILURIAN ROCKS.

As previously mentioned, these rocks do not occur in the county, but good sections of them are laid open to view along the south shore of Belfast Lough, and generally on the coast of County Down. They consist of greenish and grey grits and occasional conglomerates, with olive, grey, and black shales and slates, the black shales containing graptolites in abundance, especially at Coal Pit Bay, a little south of Donaghadee, where types of both Ordovician and Silurian systems have been found.

LOWER OLD RED SANDSTONE.

Between Cushendall and Cushendun a considerable thickness of this formation occurs, resting with a strong unconformability

FIG. 1.—FAIR HEAD AND CARRICK MORE LANDING-STAGE, LOOKING EAST. CARBONIFEROUS ROCKS AND COLUMNAR INTRUSIVE DOLERITE.—*A. McHenry.*

on the Metamorphic rocks. It consists of massive red and brown pebble conglomerates and sandstones, with occasional lenticular red and brown shaly beds. The basal portion, which is on its western margin, is mainly composed of well rounded boulders and pebbles of quartzite, of all sizes from that of a pea to over a foot in diameter. Occasionally pebbles and blocks of porphyry occur, as well as mica-schist fragments. As we ascend in the series, fragments of igneous rocks (felspathic) become more frequent, while in the uppermost beds, which are on the sea-shore at Cushendall, the rock is almost exclusively composed of angular and sub-angular boulders and detritus of the quartz-porphyry that is found in mass on the south, between Red Bay and Cushendall. In fact the rock has all the appearance of a vast volcanic breccia, some of the enclosed lumps of felstone being several feet in diameter, the matrix of the rock being also entirely composed of igneous material or débris.*

* See sketch, page 8, *Memoir* to Sheet 14.

These rocks dip steadily south-east at an average angle of 40° and the estimated thickness is about 5,000 feet. Generally speaking they bear a strong resemblance to the so-called "Dingle Beds" of the central and south-west portion of Ireland, and they are believed, with very good reason, to be of the same age. They can best be seen along the coast-line, where there is a continuous section of them laid bare, also at the old sea-caves of Cushendun where, as before mentioned, the basement-beds occur.

Carboniferous Rocks.

These are confined to the north-east of the county, in the vicinity of Fair Head, and are with good reason believed to be the equivalents of the Lower Carboniferous coal-bearing strata of Scotland. Admirable sections of the rocks can be seen in the cliffs extending from Ballycastle Collieries round under Fair Head to Murlough Bay, and at a few places in the river cuttings inland (Fig. 1).

The basal beds are coarse whitish, brown, and red conglomerates and sandstones. Junctions with the underlying schists are visible on the coast at Murlough Bay, and inland at a place about a mile S.S.E. of Ballycastle.

There occurs here a single bed of bluish-grey, highly fossiliferous limestone, six to eight feet thick, which is supposed to represent the great Lower Carboniferous Limestone of the central plain of Ireland, it having thinned out to these meagre proportions in the extreme north.

Several fairly good seams of coal were discovered and worked in this area, as was also the bed of Black Band Ironstone that occurs associated with them. These collieries are believed to be amongst the earliest workings in the British Islands.*

The usual black and dark grey shales and sandstones and conglomerates of the formation are to be seen along the coast sections from the Salt Pans, Ballycastle Bay, round under Fair Head, to Murlough. I believe that some of the black shales are oil-bearing, like those in Scotland.

Fossils are abundant throughout the series. Lists of them, and descriptions of the various coal-seams and associated rocks, are published in the Geological Survey Memoirs on the district, and also in Griffith's Report, 1829.

These Carboniferous rocks have been extensively invaded by basalt sheets and dykes, the former having intruded in a striking manner along and across the bedding planes for great distances. Sheets from half an-inch to several feet and even yards in thickness, and of regular and uniform dimensions, can be traced in the cliff faces at several points round the base of Fair Head Cliff. In some instances, as the main mass of the Fair Head dolerite is approached, the black shales have been truncated, broken up

* See *Memoir* to sheets 7 and 8 of the Geol. Survey Map, p. 12: also Griffiths' *Report*, 1829.

into lenticular fragments, and enveloped in the dolerite, and indurated into hornstone or lydianstone.*

On the south side of Belfast Lough, close to Holywood, Lower Carboniferous strata are exposed along the shore in close proximity to Permian and Triassic rocks, the former appearing to lie directly on them.

PERMIAN ROCKS.

As before mentioned, these rocks do not occur in County Antrim, but they are found on the seashore at Holywood, a few miles north-east of Belfast, and appear to rest unconformably on the Lower Carboniferous beds. They consist of buff, brown, and reddish marly sandstones and contain undoubted Permian fossils, such as *Producta horrida*, *Bakevellia antiqua*, *Schizodus Schlotheimi*, and *Turbo helicinus*.

TRIASSIC ROCKS.

The Triassic rocks, consisting of Bunter Sandstone and Keuper Marls, are well represented in the neighbourhood of Belfast, and generally on the south coast of the county, and also in County Down, where good sections of them are to be seen in the Scrabo Hill quarries. They consist of obliquely laminated red, buff, and grey sandstones with shale bands, the total thickness being probably about 800 feet (Fig. 2).

The Keuper marls form the flank of the escarpment of the Chalk, and are exposed in many places round the south and east coast, and at a few places in the north-east, where they thin out to a few yards in thickness, as at Murlough Bay and Torr Head. They are not represented at all between Fair Head and Portrush. The strata consist of bright red laminated marl with bands of sandstone and veins of gypsum, the lower portion being sometimes a coarse breccia, as at Red Bay, near Cushendall. Good sections are exposed in the railway-cutting south of White Head. The greatest extent is in the neighbourhood of Carrickfergus, where it is estimated the total thickness cannot be far short of 900 feet.

At Duncrew, near Carrickfergus, a thick deposit of Rock Salt occurs in the marls, or rather below them. The following is the section of the shaft at the salt mines:

	Feet.	Inches.
1. Drift (Boulder Clay)	50	0
2. Red marls with bands of gypsum	500	0
3. Rock Salt (1st Bed)	15	0
4. Salt and blue band	6	8
5. Rock Salt (pure) (2nd Bed)	88	0
6. Blue and red band with some salt	17	0
7. Mixed salt and blue and red band	13	0
8. Rock Salt (pure) (3rd Bed)	39	0
9. Thin blue band	6	6
10. Dark coloured rock, Freestone, and grey rock	16	4
	751	6

* See figures on page 30, *Memoir* to sheets 7 and 8.

It will be seen from this section that there is a total thickness of 150 feet of saliferous strata. The deposit is probably at the base of the Keuper division, or perhaps in the upper limits of the Bunter.

In the neighbourhood of Red Bay, Glenariff, the lower portion of the Keuper forms a coarse brecciated and massive conglomerate, a fine section of which is to be seen at the tunnel on the coast road. At this point it rests directly upon the Lower Old Red Sandstone, and is largely made up of the débris of that formation, so that it is sometimes difficult to say where the Trias begins and the Old Red Sandstone ends. There are fine sections of both strata along the coast between Red Bay and Cushendall.

RHÆTIC BEDS.

Cropping out here and there from beneath the Liassic beds, along the escarpment, are to be seen sections of these rocks. They consist of black and dark grey shales and calcareous oolitic beds, and contain *Avicula contorta*, *Cardium Rhæticum*, and other characteristic fossils of the formation in abundance. Collin Glen, south-west of Belfast, Woodburn Glen, west of Carrickfergus, and the shore at Waterloo, a little north-east of Larne, are the best places to see sections of the beds. The latter place is particularly rich in fossils, amongst them being found a star fish, *Ophiolepis Damesii*.*

LIASSIC ROCKS.

Lower Lias occurs almost continuously along the escarpment of the Chalk round the south-east and north of the county. The formation consists of dark blue and grey mud and shale, with irregular nodular beds of grey limestone. Fossils are very abundant throughout, especially on the west side of Island Magee and at Larne, also at White Park Bay, Ballintoy, and near Kinbane Head in the north, and also at Portrush.

Considerable landslipping takes place on the Lias mud, especially along the coast between Glenarm and Red Bay, in consequence of which it is difficult in winter time to keep the coast road clear for traffic, and this can only be done by constant attention (Fig. 2).

In some instances the Lias has been highly indurated by the intrusive dolerite, as at Portrush, where it has been converted into hornstone resembling fine-grained basalt; in fact, it was described in early days as basalt, though fossils occur in it.

CRETACEOUS—UPPER GREENSAND.

This division of the Cretaceous attains its greatest thickness in the south-east, in the neighbourhood of Collin Glen, Belfast, and near Carrickfergus and Larne, where it is fully 30 feet thick or more. Towards the north, however, it thins out completely,

* See lists in Geological Survey *Memoir* to sheets 21, 28, and 29, pp. 39-42.

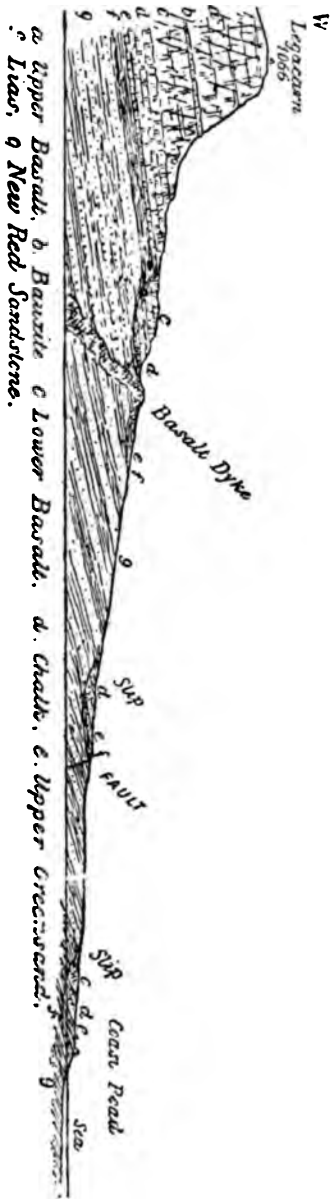

FIG. 2.—SECTION TWO MILES S.E. OF GLENARM.—*R. G. Symes.*

(Reduced from *Memoir* on Sheet 20 *Geological Survey of Ireland.*)

and is there represented by a quartzose pebble-bed about a foot thick at the base of the Chalk. This basal bed, however, I think more properly belongs to the Chalk than to the Greensand (Fig. 3). The Greensand is generally of a dark dull green colour, due to glauconite; sometimes it is variegated, light greenish and white, while at Larne it is reddish in colour, this being an exceptional condition.

It contains fossils in abundance, *Exogyra conica* being the most common form in the "Glauconitic Sands."*

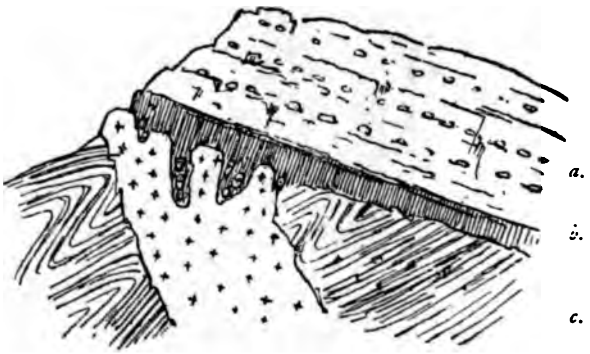

FIG. 3.—SECTION ON S. SIDE OF GREENANMORE HILL, MURLOUGH BAY.

a. Chalk with flint-layers; *b.* Basal-bed of Cretaceous Series; *c.* Metamorphic Rocks; *d.* Diorite [Camptonite] dyke.

(Reproduced by permission from *Memoir* to Sheets 7 and 8 *Geological Survey of Ireland.*)

CRETACEOUS—UPPER CHALK.

This is a very considerable and important formation throughout the whole county. It is almost in all cases found to be capped by the tabular basalt sheets of the lower division, and fine sections of it are laid open to view all round the escarpment fringing the coast line on the east and north. It is always a hard compact white rock, and contains abundance of flints, the hardness being probably due to induration produced by the superincumbent basaltic lava sheet at the time the latter was poured out on its denuded and almost bare surface.

It is very variable in thickness. In the vicinity of Belfast its average is about 80 feet, and it maintains this thickness pretty generally northwards till the high ground of the metamorphic rocks north-west of Cushendall is reached, and here it dwindles down to but a few feet in extent, as at the head of Glenshesk, on Croaghan Mountain. Northwards it again thickens out, and in

* For complete lists of the fossils, see *Memoir* to sheets 21, 28, 29, and 36.

the Ballintoy area, on the north coast, sections of over 150 feet are to be seen in the sea-cliffs, west of Carrick-a-raide. It here attains its maximum thickness, which has been estimated at about 250 feet. The upper surface of the Chalk is always much eroded, crevices and hollows having been formed in it, which are filled with eroded and burnt flints (indurated by the overlying basalt) and red and brown earthy material. A layer of this flint gravel bed invariably intervenes between the Chalk and the basalt. At several places in the interior of the county, the removal of the

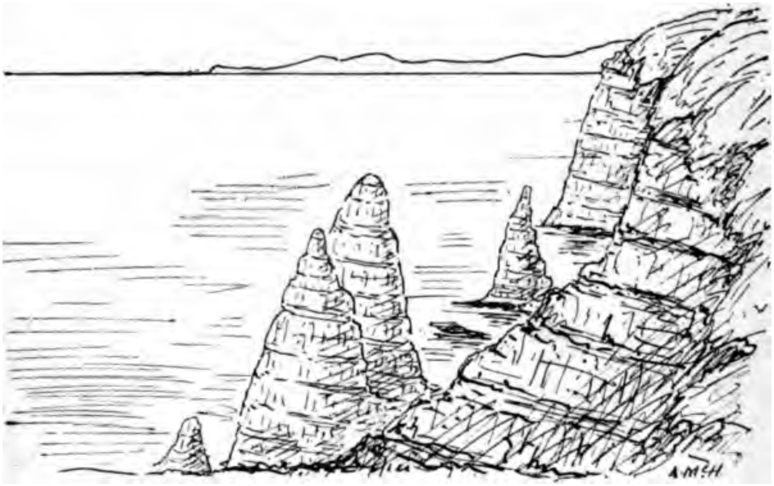

FIG. 4.—OLD SEA STACKS OF TABULAR BASALT, BULL POINT, WEST END OF RATHLIN ISLAND.—*A. McHenry.*

Doonmore	. .	about 130 feet high.	
Stacknacally	. .	" 150	"
Stackaniska	. .	" 100	"

basalt by denudation has laid bare the chalk at the surface, as at Templepatrick quarry, on the Belfast and Northern Company's Railway. These inland croppings of chalk are of great benefit to the surrounding district, as they afford to the inhabitants an opportunity of readily obtaining lime for agricultural and other purposes.

On Knocklayd mountain, south of Ballycastle, at an elevation of 870 feet above the sea, there is an outlying patch of Chalk which rests directly on the metamorphic rocks, the outcrop forming a rude triangle on the hill. It is here about 80 feet thick, and is capped by the Lower and Upper Basalts. A couple of miles to the westward, near Armoy, the Chalk is at an elevation of but 270 feet above the sea level. This shows that a

considerable fault exists between the two places, with a downthrow on the west side of 600 feet, since the bedding of the Chalk is nearly horizontal at both places—indeed the same remark applies to the Chalk throughout.

On Rathlin Island the Chalk is the foundation rock, and is at least 220 feet thick. It is similar in every respect to the mainland rock, and is everywhere capped by the basalt. (Fig. 4.)

In many places where the Chalk is in contact with large basalt dykes and masses of intrusive dolerites, it has been converted into a crystalline saccharoidal marble, as at Murlough Bay, Scawt Hill, and Rathlin. On the shore, a little to the west of Ballycastle Quay, there is an interesting, remarkable, and quite unusual lenticular deposit, several yards thick, between the Chalk and the overlying basalt. It is evidently of true

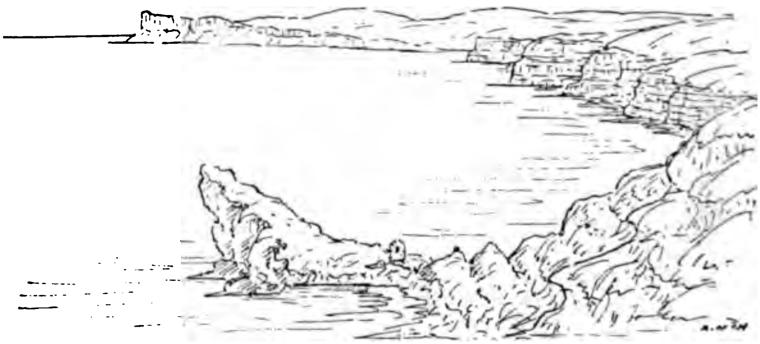

FIG. 5.—NORTH COAST OF ANTRIM BETWEEN FAIR HEAD (DOLERITE) AND KINBANE HEAD (CHALK), SHOWING CLIFFS OF TABULAR BASALT.—*A. McHenry.*

sedimentary origin, and contains fossils of Upper Cretaceous types, which are said to have been derived from the Chalk.

The material of the deposit consists of well rounded and water-worn pebbles and detritus of the underlying Chalk. It has occurred to me that it may possibly be of early Eocene age.

EOCENE BASALTIC PLATEAU.

Almost the whole surface of County Antrim, as is well known, is covered by the sheets of basaltic lava that were poured out from numerous necks, vents, and fissures in Tertiary times. These basaltic outflows can readily be, and have been by the Geological Survey, mapped out into two distinct periods of volcanic activity, Upper and Lower. They are separated by a well-defined horizon of bole, lithomarge, aluminous clay (bauxite), and pisolitic iron-ore deposits, containing beautiful and well-marked plant remains,

FIG. 6.—VIEW OF THE COAST-CLIFFS FORMING PART OF "THE AMPHITHEATRE" NEAR THE GIANT'S CAUSEWAY, SHOWING SUCCESSIVE SHEETS OF COLUMNAR BASALT SEPARATED BY BANDS OF OCHREOUS CLAY ("BOLE") AND VOLCANIC ASH.

(Reduced from *Memoir* on Sheets 7 and 8 *Geol. Survey, Ireland.*)

thus proving a long period of rest between the two great outbursts of basic lava.

The Lower Basalt is generally more massive in its flows, seldom columnar, and always more amygdaloidal in its character than the Upper division. In it, as well as in the Upper Basalt, there are beds and bands of bole between the coulées.

The Upper Basalt is always more compact in structure, more columnar, and, by one who has been accustomed to mapping the country geologically, can be very readily distinguished from the Lower. Intrusive columnar masses are also of more frequent occurrence in it. The beautifully columnar basalts of the Giant's Causeway mainly belong to this division. (Fig. 6.)

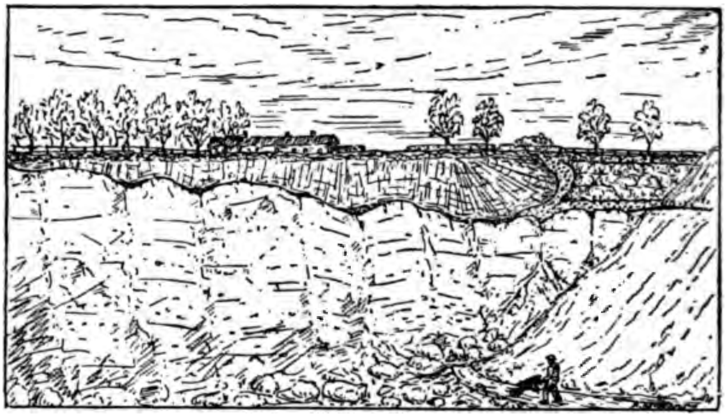

FIG. 7.—EAST END OF TEMPLEPATRICK QUARRY, COUNTY ANTRIM, SHOWING POSITION OF CHALK, GRAVEL BED, LOWER BASALT, AND RHYOLITE.—*A. McHenry.*

(Reproduced, by permission, from *Geol. Mag., June,* 1895.)

As before mentioned, the zone of the pisolitic iron-ore and bauxite can be traced in many places over the entire county, and it has been worked with considerable profit heretofore. The best known localities for the bauxite are at White Park Bay, Ballintoy, and in the Glenarm valley, where the Eglinton Chemical Co. worked it for some years. A considerable thickness of lignite occurs on this zone at Ballintoy, and at one time it was worked for coal.

The Pisolitic ore has been worked extensively in many parts of the county, notably at Ballypalady, on the Belfast and Northern Counties line, in the vicinity of Larne, Island Magee, Parkmore, at the head of Glenariff, and elsewhere, and great deposits of it

still remain available both on the mainland and on Rathlin Island.

A remarkable incident took place during the period that elapsed between the Upper and Lower Basaltic outbursts, namely the protrusion of the Rhyolite (usually called Trachyte) which occurs in mass at Sandy Braes and Tardree Mountain, north-east of Antrim, and at Templepatrick and a few places in the vicinity of Ballymena and Broughshane. Unmistakable evidence as to the age of the Rhyolite, in relation to that of the Upper and Lower Basalt, was some years ago, and probably is still, to be seen at Templepatrick Quarry, an account of which has lately appeared in the *Geological Magazine*.

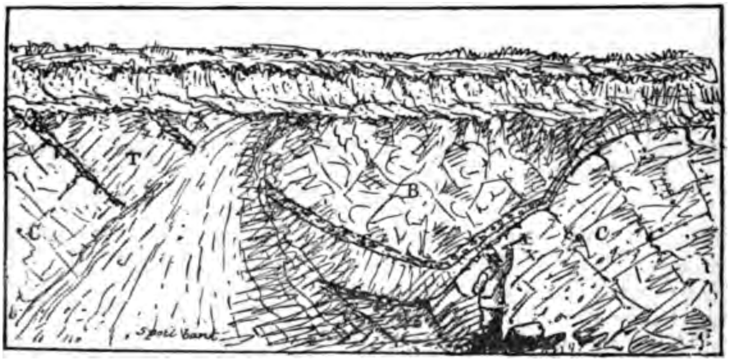

FIG. 8.—WEST END OF TEMPLEPATRICK QUARRY, COUNTY ANTRIM.—*A. McHenry.*

C Chalk. G Flint-Gravel Bed. B Lower Basalt. T. Rhyolite.

(Reproduced, by permission, from *Geol. Mag.*, June, 1895.)

The sketch (Fig. 7) of the east end of Templepatrick Quarry is copied from this paper.* It shows that the rhyolite has been erupted in the form of a laccolite into the Lower Basalt series, and that it has swept the sub-basaltic flint-gravel before it as it advanced, piling it against the pre-existing Lower Basalt, and indurating it into a hard, compact, flinty mass of rock. The radiating columnar jointing of the rhyolite, a structure which always tends to set itself at right angles to the surface of a cooling mass, shows that the present outer margin of this rock was such a cooling surface. This conclusion is emphasised by fine flow-bands parallel to the same outer margin.

The next figure (Fig. 8), illustrating the west end of the same quarry, shows the rhyolite forcing its way underneath the basalt

* *Geol. Mag.*, Dec. 4, vol. ii, p. 260.

along the bed of flint gravel, which it carries on its back ; at one place portions of the gravel bed rest both above and below it.

The two theoretical diagrams which follow (Figs. 9, 10) explain the facts observable in Templepatrick Quarry. In the

E W.

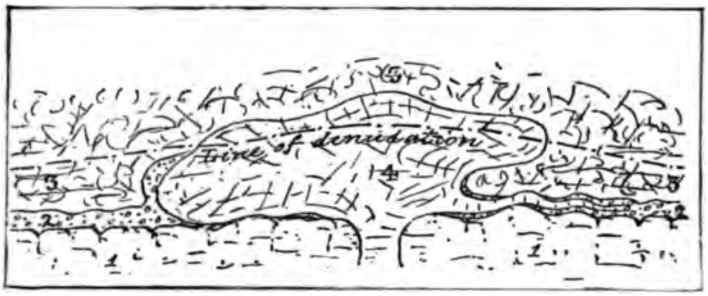

FIG. 9.—IDEAL SECTION SHOWING PROBABLE MODE OF INTRUSION OF THE RHYOLITE THROUGH CHALK AND LOWER BASALT.

1. Chalk with eroded surface. 2. Flint-gravel bed, composed of burnt chalk flints, chalk fragments, and red marly clay. 3. Lower Basalt. 4. Rhyolite (laccolite).

first the intrusion of the laccolite into the Lower Basalts is shown, followed by the denudation of both rocks. In the second diagram the subsequent deposition of bole and ash, succeeded by the Upper Basalt, is illustrated.

That the intrusion had taken place before the period of the Upper Basalts is proved by the two following sections (Figs. 11, 12), which represent the succession of Eocene rocks at Ballypalady and Glenarm respectively. At both places layers of rhyolite

E. W.

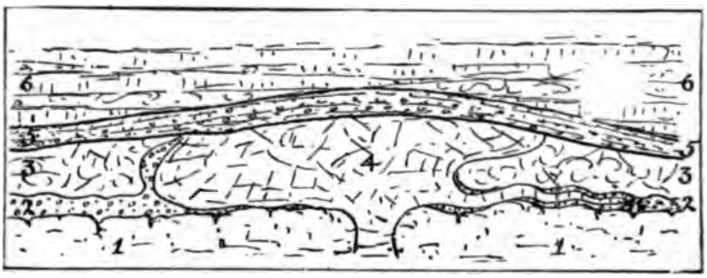

FIG. 10.—IDEAL SECTION SHOWING PROBABLE POSITION OF THE ROCKS (PISOLITIC IRON-ORE, RHYOLITE GRAVEL, AND UPPER BASALT) OVER THE RHYOLITE AND LOWER BASALT.

1. Chalk. 2. Gravel bed. 3. Lower Basalt. 4. Rhyolite. 5. Horizon of denudation, along which were deposited the pisolitic iron-ore bed, rhyolite conglomerate and sand, basaltic and ferruginous conglomerates, marls, and bole, containing plant and other remains. 6. Upper Basalt.

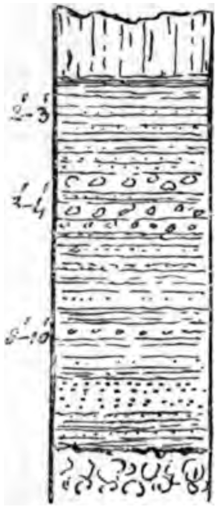

FIG. 11.—BALLYPALADY SECTION, 1½ MILES NORTH-EAST OF TEMPLEPATRICK.

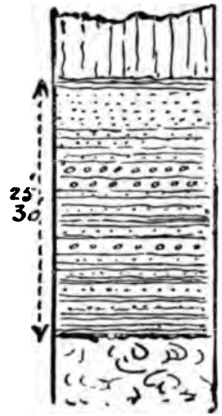

FIG. 12.—LIBBERT MINE SECTION, GLENARM.

gravel and conglomerate occur amongst the interbasaltic bole, ash, and plant beds. This deposit proves that denudation had penetrated through the cover of Lower Basalt into the rhyolitic laccolite before the Upper Basalts were poured out.

The Rhyolite, therefore, may be regarded as, so to speak, of mid-basaltic age, *i.e.*, occurring between the periods of the Lower and Upper Basalts (see Fig. 2). I may here mention that I regard it as highly probable that the granite of the Mourne Mountains is contemporaneous with the Rhyolite of County Antrim.

The estimated thickness of the Lower Basalt is about 700 feet, that of the Upper between 400 and 500 feet.

Among the plant remains found in the deposit between the Lower and Upper Basalts at Ballpalady and Glenarm are: *Pinus*, *Sequoia*, *Cupressites*, *Rhamnus*, *Quercus*, etc. Mr. J. Starkie Gardner considers the deposit to be of Early Eocene age.

Volcanic Necks or Vents of Tertiary age are well represented

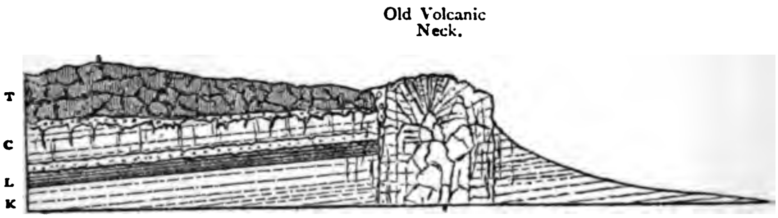

FIG. 13.—OLD VOLCANIC NECK, CARNMONEY HILL.—*E. Hull.*

T. Lower Basalt. C. Cretaceous Beds. L. Lower Lias. K. Keuper Marls.

(Reproduced, by permission, from *Memoir* to Sheets 21, 28, and 29, *Geol. Survey of Ireland.*)

at several places, notably at Carrick-a-raide, on the north coast; Tieveragh Hill, near Cushendall; Scawt Hill, south-east of Glenarm; Sleamish Mountain; and Carnmoney Hill. (Fig. 13.)

The vent of Carrick-a-raide is the most important, and perhaps the most extensive in the county. It measures fully 1,200 feet across its central core, and from it spread out, in every direction, vast sheets of ash-beds which can be traced for miles in the sea-cliffs on either side of it. The vent itself is filled with massive tough grey volcanic agglomerate containing angular and rounded boulders and huge chunks of basalt, chalk fragments, and later basaltic dykes and squirts. A fine view of it can be had from the swinging bridge and from Carrick-a-raide itself.

The Tieveragh vent is a pipe of basalt coming up through the Old Red Sandstone, which it indurates for some distance all round, converting the red sandstones into a hard, siliceous grey rock.*

* See sketch in *Memoir* to sheet 14, p. 19.

Scawt Hill vent is also of considerable extent and importance, and the rocks surrounding it have undergone very remarkable change by contact metamorphism. The chalk has been here converted into a grey saccharoidal crystalline limestone, resembling in every respect some of the crystalline limestones of the old metamorphic series, such as those at Torr Head and elsewhere.

Basalt dykes and intrusive dolerites are of frequent occurrence throughout the whole region, and generally present a more or less columnar structure, Fair Head, Ballygally Head, and Brocky set quarry, near Ballintoy, being examples of the intrusive dolerites. The Fair Head laccolite is massively, rudely, and vertically columnar, the columns at the "Grey Man's Path" measuring 250 feet.*

Igneous rocks of earlier types occur as intrusive masses and dykes amongst the old metamorphosed sediments. At Torr Head there are basic varieties associated with the schists. They were evidently intruded prior to the metamorphism, as they have been converted into epidiorites by the post-Silurian earth movements. Fine sections of these epidiorites and crystalline limestones, with micaceous and quartzose schists, are to be seen at the coastguard watch-house. There are also some narrow dykes of later diorites, occurring in these schists at Green Hills and Ruebane Head (Camptonite, Fig. 3), west of Torr, and close to Murlough Bay.

On the north-west of Cushendun a considerable mass of red granitic rock—microgranite—intrudes into the schists. Dykes and veins of similar rock are also to be seen coursing and penetrating the metamorphosed sediments at many places near the road that leads from Cushendun to Torr Head.

In the vicinity of Cushendall a large tract of quartz-porphyry exists, which is evidently of pre-Devonian age, as the Lower Old Red Sandstone in its upper parts is mainly composed of the débris of it. This rock is very varied in colour, from red to brown, grey, dark blue, and purple, and in some instances almost black. It is compact in texture and contains blebs of quartz, sometimes porphyritic felspars, and often veins of red jasper. Good sections of it are to be seen close to Cushendall at several places.

POST-PLIOCENE.

Boulder Clay is very generally distributed over the whole county, and is to be found even on the highest hills in considerable extent. Some of the river valleys exhibit sections of it up to 70 feet thick, especially in the north. It is sometimes very full of stones, and contains enormous boulders, one of which, a schist block, that occurs in Glendur, measured 25 by

* See sketch in *Memoir* to sheets 7 and 8, p. 38.

18 by 15 feet. In the Carey River valley a boulder of Fair Head dolerite measured up to 1,600 cubic feet.

Sand and gravel is also pretty generally spread over the country.

In the Carey River, east of Ballycastle, there are fine examples of old river terraces, the first being about 250 feet above the sea level, and from that up to 600 feet there are several others. A fine view of them is to be had from the high level old road leading from Torr Head to Ballycastle.

Recent Accumulations.

Peat Bog, as before mentioned, occurs plentifully in many districts, especially in the north, in the Moss side area, where it occupies an extensive tract of low ground. It is also very generally spread over the high ground of the Glens of Antrim, the highest hills being covered by thick coatings of it.

Raised Beaches.—Worked flints of Palæolithic age are very common in the raised-beach gravels and sands that fringe the coast. Notably at Larne Harbour, Kilroot, White Park Bay, west of Ballintoy, and at Portrush and Portstewart. At Ballintoy abundance of well finished examples were obtained, associated with hammer stones and corn crushers or querns of primitive pattern. Many fine specimens of pottery were also found at Ballintoy, some of which show ornamentation and carving. At Portrush and Portstewart also extensive finds of flint and stone implements and pottery have been made from time to time. At all these places bones of various animals are found associated with the implements, the limb bones of the larger animals being invariably broken, evidently to obtain the marrow. Kitchen middens of sea shells (limpets and periwinkles) are abundant along the sand hills of White Park Bay, Portrush, and Portstewart.

Old sea caves and sea stacks exist at many points. Examples of the latter are to be found near Ballycastle, Ballintoy, and on Rathlin Island* (see Fig. 4). The sea caves are numerous, and large collections of the bones of various animals have been obtained from them, notably from those near Ballintoy.†

Blown Sands.—A considerable extent of the coast line on the north is occupied by these sands. They occur near Ballycastle, at White Park Bay, along the mouth of the River Bush, and at Portrush, where the dunes extend for over two miles.

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* See also fig. on page 36, *Memoir* to sheets 7 and 8.

† See *Rep. Brit. Assoc.* for 1834, pp. 658—660.

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THE MOURNE MOUNTAINS.

By R. LLOYD PRAEGER, B.E., B.A.

(Read 5th July, 1895.)

THE Mourne Mountains, anciently Beanna Boirche (the Peaks of Boirche, an Irish chieftain) form the most elevated land in Ulster, and one of the most picturesque mountain-groups in Ireland. They are situated in the southern extremity of County Down, surrounded by a fertile, undulating tract of drift-covered Ordovician rocks. The mountains cover an elliptical area of about fourteen miles by seven, the longer axis of which runs approximately north-east and south-west. At their eastward extremity, the Mournes descend steeply into the Irish Sea, and at their western end drop with equal abruptness into the sheltered waters of the beautiful Bay of Carlingford. To the southward, a long slope stretches away from the bases of the hills to the water, this surface being formed by a deposit of drift of great extent and thickness, which offers to the sea a wall of pebbly clay and gravel, often thirty to forty feet in height. To the northward, across a hummocky valley of Ordovician rocks, the Slieve Croob range (1755 feet) rises in the centre of County Down, composed of granite rocks much more ancient than those which form the higher and adjoining grounds of Mourne.

The Mourne Mountains are the denuded remains of a mass of intrusive rock that has thrust itself through the thick Ordovician series, which stretch from County Down away south-westward across Armagh and Monaghan into Cavan. This intrusive rock is a fine-grained and very tough grey granite, passing into the "granophyre" of many authors; it is composed of quartz, orthoclase, albite, and green or black mica.

In the one day which, according to the programme, the Geologists' Association will spend in the Mourne Mountains, during their approaching visit to the North of Ireland, the members will traverse, of course, but a very small portion of the range; this will be enough to give them a good idea of the geological and physical features of the district, but must be regarded as only an introduction to the interest and beauty of this fine mountain-group. The present notes, therefore, need not deal with stratigraphical or petrological details, for which the reader is referred to sheet 60 of the 1-inch map of the Geological Survey of Ireland, and to the memoir which accompanies it; nor need I describe minutely the route which the Local Committee has selected for the members of the Association, since this is sufficiently indicated in the programme. It seems more appropriate to deal with the general physical features of the range, in order to convey an impression of the district as a whole, and to aid those who may elect to make a closer and fuller acquaintance with a neighbourhood so well worthy of their study.

In the mountain district of Wicklow, which was visited by the Association two years ago, and in that of Antrim, which they are about to explore, the summits are in general somewhat scattered; fertile valleys intervene, and as a consequence good roads traverse these regions in various directions. The Mourne district, on the contrary, resembles the beautiful Twelve Bens of Connemara, and the summits are grouped close together, with deep valleys between them, bounded by high rocky ridges, road-making being thus rendered unprofitable and difficult. In the Mournes one road alone crosses the range—that which ascends the course of the River Bann from Hilltown, passes across the boggy waste called the Deer's Meadow, and, crossing the watershed at an elevation of over 1200 feet, drops down under the slate and granite cliffs of Pigeon Rock Mountain to the lower grounds behind Kilkeel. The more interesting mountains, and all the higher peaks, lie to the eastward of this north and south line; and to this eastern half of the range, therefore, our attention may be chiefly directed. Here we have a horseshoe-shaped chain of peaks, starting with Spence's Mountain on the south-east, and including Chimney Rock (2152 feet), Slieve Donard (2796), Slieve Commedagh (2512), Slieve Bearnagh (2394), the two Slieve Meels (2310 and 2237), and terminating on the westward with the long ridge of Slieve Muck (2198). Down the centre of the interior of this horseshoe runs a second high ridge, whose principal summits are Slieve Lamagan (2306) and the huge and splendid mass of Slieve Bingian (2449). Between this central ridge and the horns of the horseshoe lie the two finest valleys of the district—those of the Annalong River and Kilkeel River. Most of the summits are dome-shaped, as is usually the case with granite mountains; but some of them, notably Slieve Bearnagh and Slieve Bingian, are crowned with glorious crags, where on the calmest day the wind sings through the crevices, and rustles the shining leaves of the dwarf willow, the cow-berry, and other alpine plants. The mountain-sides are in general steep, but fairly smooth; but in many places great cliffs overhang the valleys, and it is worthy of note that, almost without exception, these precipitous descents are on the eastern sides of the hills. Thus the cliff-ranges of Slieve Beg, Cove Mountain, Bencrom, Pigeon Rock, and Eagle Mountain, all face to the eastward.

As would be expected from the steep slope of the ground, lakes are few, and those which occur appear to be formed by a dam of moraine matter lying across the valley which contains them. The largest piece of water among the mountains is Lough Shannagh (the Fox's Lake), about half a mile by a quarter mile in diameter, lying at an elevation of 1350 feet. The Blue Lough is most picturesquely situated in a deep hollow between Slieve Lamagan and Slieve Bingian, and Lough Bingian is perched on a shelf of the mountain above. Several of the

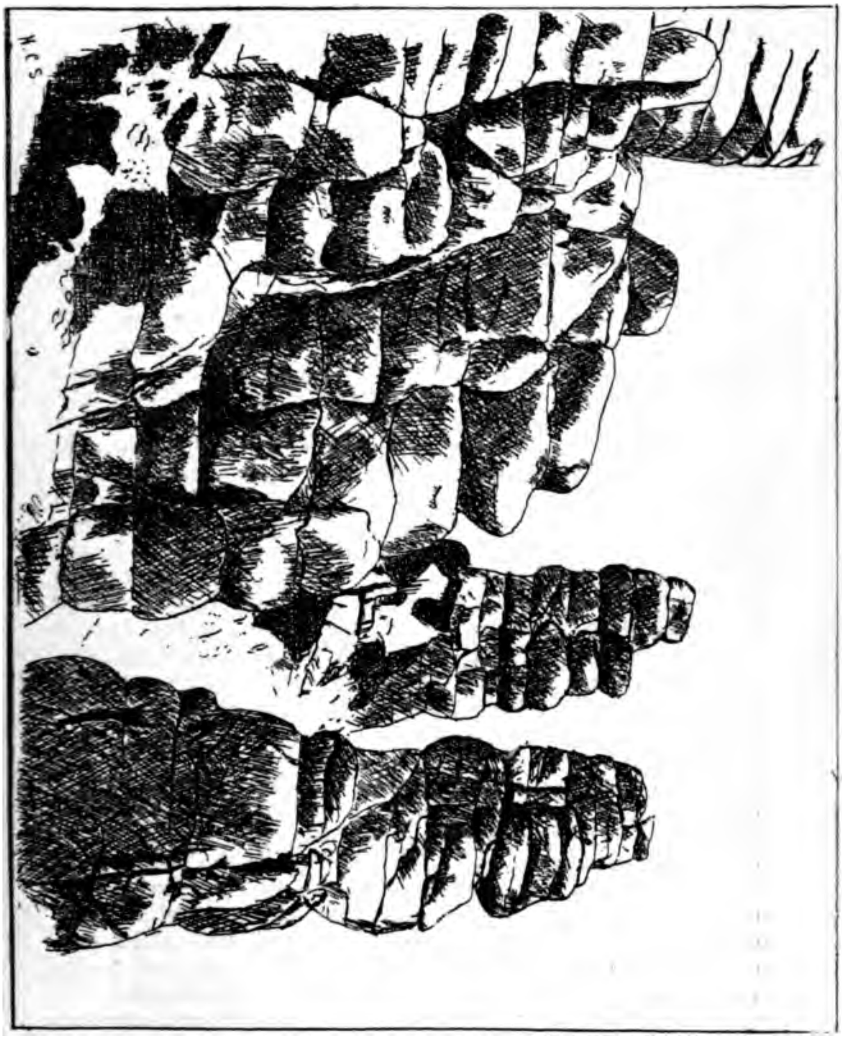
valleys contain well-marked moraines. The most noticeable is that which blocks the glen of the Kilkeel River, below Moolieve. There a great bank of stones and gravel extends almost across the valley, and the effect of its obstruction is evident in the flat alluvial plain that fills the valley-bottom for fully two miles up-stream. In many places the usual signs of glaciation are apparent, ice-rounding, rock-striation, and *roches moutonnées*, may be seen in various directions. Around the mountains, the deposits of the general glaciation of Ireland appear to be obscured by the débris of the local glaciers, and the coarse, gravelly, unfossiliferous moraine-matter of the district will be found less interesting than the fossiliferous Boulder Clays. The latter are well developed in the neighbourhood of Belfast, and elsewhere in the counties of Down and Antrim.

The most important river of the district is the Bann, which rises on Slieve Muck, and goes foaming down the steep descent below Spelga Mountain on its long course of ninety-eight miles to the northern ocean. Its mouth lies near Portrush, a place to be visited by the members of the Association on the last day of their tour. The Annalong River, Kilkeel River, White Water, etc., flow southward into the Irish Sea.

The Ordovician grits, considerably altered by their contact with the granite, lap round the flanks of the mountains. They seldom rise higher than a thousand feet, but in the neighbourhood of Slieve Muck they have been carried up on the top of the intruding mass of granite, forming the summit of Slieve Muck North (2198 feet); and they may be seen capping the precipitous ridge that runs southward for about a mile, with the granite clearly below them. Along the sea-shore south of Newcastle, in the beds of various streams, and elsewhere, we may observe how the grits and sandy shales have been altered into a very hard and fine-grained rock, in which the stratification is rendered beautifully distinct.

The granite is usually traversed by several series of joints, and these play an important part in the scenery of the range. Thus, a strong series of vertical and horizontal joints at the Castles of Commedagh (which will be visited by the Association) has conduced to the formation of the grand bastions and jointed columns of that picturesque spot. On the western side of Slieve Bearnagh, a set of great parallel joint-planes, dipping at a somewhat high angle, has produced the enormous slopes of bare granite that face across the valley to Slieve Meel More. Elsewhere, as on the precipice below Cove Lough, the strong horizontal jointing gives the cliffs the appearance of gigantic walls of ashlar masonry.

In many places the granite is full of drusy cavities, which are lined with beautiful crystals of smoky quartz, orthoclase, black mica, and, less commonly, amethyst, beryl, and topaz. This character will be seen in perfection at the Diamond Rocks, on the southern slope of Slieve-na-glough.



CASTLES OF COMMEDAGH, SHOWING GRANITE WEATHERING INTO PINNACLES.

Should any of the members of the Geologists' Association decide to spend a few days in exploring the Mourne Mountains, I believe they will consider themselves amply repaid for their trouble. There is a marvellous charm about these great brown hills, where the silence is broken only by the murmuring of the streams and the bleating of the sheep; these huge walls of granite, tenanted by the Peregrine and the Raven; these deep quiet valleys, and these lonely mountain tarns. Slieve Bingian alone will furnish a charming day's work; and the glen of the Kilkeel River is undoubtedly one of the finest mountain valleys in the kingdom.

While the mineralogist will delight in the famous druses of the main granite mass, the geologist will find the relative ages of the rocks of Mourne of considerable interest. The eastern coast of the district is traversed by abundant basic igneous dykes, the variolites of Annalong and Dunmore Head occurring among them. These dykes are cut off by the granite, which is itself traversed by later grey-green basic dykes, such as are occasionally met with upon the open moors, in contrast to the pale surfaces of granite. The Mourne granite has often been compared with the similar rocks of Mull and Skye; and there is every reason to believe that it is also of early Cainozoic age. When describing the variolite of Annalong, Prof. Cole suggested that the earlier series of dykes, clearly post-Ordovician, was really post-Cretaceous; and he informs me that his observations in County Antrim have led him to correlate these dykes with the first series of basalt-flows in north-east Ireland, the granite of Mourne, in consequence corresponding with the rhyolitic eruptions of Tardree. The latter basic dykes of Mourne would then represent the "upper basalts" of County Antrim. This view has, I am informed, been arrived at independently by the officers of the Geological Survey of Ireland*; and the Eocene age of the granite, at any rate, may be accepted almost without reserve.

The phenomena of successive intrusions and of contact-intermingling around the margins of the mass deserve in these days close attention. Prof. Sollas has rendered the region of Carlingford Mountain, south of the Mournes, classic as an example of the manufacture of new rocks from the interpenetration of two older ones; and a local case of the refusion of a basalt dyke by an invading eurite has been studied at Glasdrumman by Prof. Cole. The examination of the district may be rendered complete by a visit to the metamorphosed Ordovician strata on the shore, and thence to their less altered representatives, famous for their graptolites, in the north-east lowlands of County Down.

* See *ante*, p. 144.

NOTES ON THE HIGH-LEVEL RIVER DRIFT BETWEEN HANWELL AND IVER.*

By J. ALLEN BROWN, F.G.S.

(Read 3rd May, 1895.)

THE high-level river drift deposits between Hanwell (Middlesex) and Iver (Bucks) have been chosen as the subject of this paper because the exposures in that district present features of great interest and importance. These deposits have been under careful investigation by me for many years as fresh sections have been exposed, and from my voluminous notes thereon, I have selected for the purpose of this paper such as may serve to indicate the general character of these high-level drifts, their probable origin and formation.

The evidence which will be brought forward will show that some, at least, of the deposits under review, are not the result of simple fluviatile agency, as has been generally supposed, but that large accumulations of ice-borne material seem to have actually formed at the time the river flowed at levels from above 180 ft. O.D. down to below the 75-foot contour in the districts under investigation.

Further than this, it will be suggested that vast masses of frozen gravel, sands, and clay were carried bodily into the stream itself, where they remain until to-day to tell their story. To such deposits (the result of combined river- and ice-action) it is proposed to apply the term Fluvio-Glacial. In proposing this term for the very high-level drifts, it should be understood that the word glacial is employed in a local sense, and signifying, as Mr. Whitaker says, "the occurrence of very cold or icy conditions."

I would include in the Fluvio-Glacial deposits, as will be seen in the description of the sections, some of the deposits now described on the drift maps as "Glacial." It is difficult to distinguish them either in structure or composition from some forms of drift hitherto considered as fluviatile. They occur, among other places, west of Uxbridge and Hillingdon, and west of the Colne Valley, and are only separated from known river drift by narrow patches of lower Tertiary, from which the drift has been denuded.

It will be shown that these so-called glacial deposits are found, like the river drift, descending the slope of the hills from the higher ground to the north in Middlesex and Bucks to the same level as, or even to a *lower* contour than, the known river drift at Uxbridge Common, Hillingdon, etc. Alluding to these drifts, Mr. Whitaker has said: "The glacial drift may contain beds

* This paper was read with special reference to the Excursion of 4th May, 1895, for report of which see *ante*, *Proc. Geol. Assoc.*, vol. xiv, p. 118.—ED.

which are not of distinctly glacial origin; but there seems to be no need of using a special word for such and calling them Interglacial. They are part and parcel of the formation—mere interludes as it were—showing only some temporary or local changes."*

Palæolithic implements have been found throughout the whole district under investigation, generally in the stratified beds, but also much abraded specimens in in-filled furrows, showing that man existed in this neighbourhood from the earliest period which the beds record, even when the stream flowed over and eroded the London Clay. A few specimens in my collection are of the peaked and other plateau types, discovered by Mr. B. Harrison on the Chalk escarpment in Kent, and described by Professor Prestwich.†

In others, the angles of fracture are almost obliterated by abrasion, and the surfaces partly decomposed by the action probably of humic acid or other solvent. These rude and half-obliterated implements seem to have been, in many cases, swept off the ground by the same agency which removed the gravel, clay, and sand from the surface and deposited it at lower levels. Some of these specimens have been found at the high level of 180 O.D.

I now propose to describe sections of Drift in the localities hereinafter mentioned.

HANWELL.

A little north of the large iron bridge which crosses the Uxbridge Road at Hanwell, and a short distance south-east of the "Mill ponds," there is a gravel pit, which, for many months past, has presented a very remarkable illustration in conformation of the foregoing remarks (see Fig. 1). In the section lately shown the depth of the excavation was over 20 feet, the base of the drift not being seen. At the base of the section is a horizontally stratified bed of gravel and sharp sand, of which a thickness of 7 or 8 feet is exposed.

Reaching from the bottom of the brick earth and trail to beyond the lowest part of the face of the excavation, is an irregular furrow or depression, from 16 to 18 feet wide at the top, or widest part, and varying from 11 to 12 feet in depth. It penetrates deeply into the stratified bed, which is disturbed and contorted on both sides of the furrow, being, in fact, in some places, bent beneath, and, at the sides, following the form of the funnel-shaped deposit. In the centre of the channel, near the top, is a large irregular patch or included deposit of blue silty clay and bleached pebbly gravel, in striking contrast to the yellow and ochreous gravel which encloses it. There are also, in other

* *Geology of London*, p. 299.
† *Quart. Jour. Geol. Soc.*, vol. xlv (1889), p. 270.

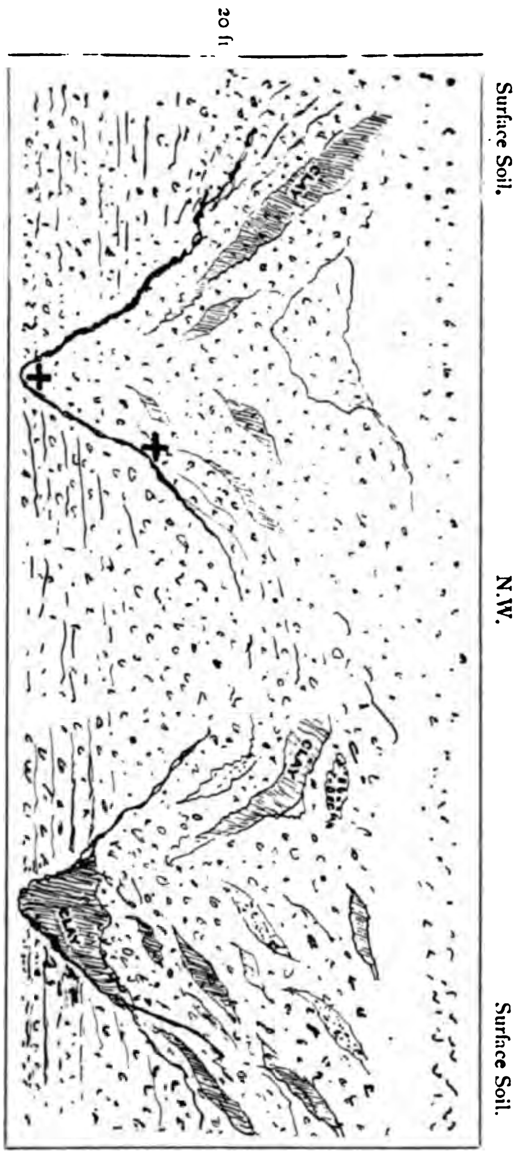


FIG. 1.—SECTION AT HANWELL (GIBSON'S PIT), SHOWING FURROWS IN STRATIFIED GRAVEL.

+ Implements found here.

parts of the depression, irregularly formed deposits of the same blue clay, sand, and whitened pebbles, and sub-angular gravel, with ochreous gravel in other places, thus filling the furrow—this furrow had been almost cut away by the pitmen when the members visited the pit on the 4th May, but a similar furrow was then seen close to it. Above the irregular, and, apparently, eroded top of the filled-in furrow, is a mottled sandy clay, or brick earth (not the usual brown stiff clay most frequently met with), 4 or 5 feet thick, surmounted by a scattered deposit of clayey gravel (trail).

This wide, deep furrow, or channel, has been traced by me for 150 feet, but it probably exceeded that amount in length. The gravel deposits in this locality do not extend far to the north, though they can be traced up to the higher ground to the N.E., on which Hanwell Church is built.

There can be no doubt that the drift must, from the position of the deposit, have once extended to the north, where is now the Brent Valley, but it has been denuded, and erosion has taken place in the London Clay beneath.

The gravel in the furrows is of a different character from the stratified beds in which numerous "erratics" are found, and I found its composition to be as follows:—

Pebbles, including seven or eight black ones, probably derived from the Eocene	78
Fragments of white crusted Flint nodules abraded	3
Small Quartzite Pebble	1
Sub-angular Flints, some bleached	14
Small Ragstone Pebble	1
Small Quartz Pebbles from the size of a small pea to a small marble	3
	100

This analysis may be taken as a fair representation of the contents of many other furrows, and it contrasts with that of the stratified bed which contains purple and yellow quartzites, quartz, etc., in the form of small boulders, and, very rarely, flints with a bleached surface.

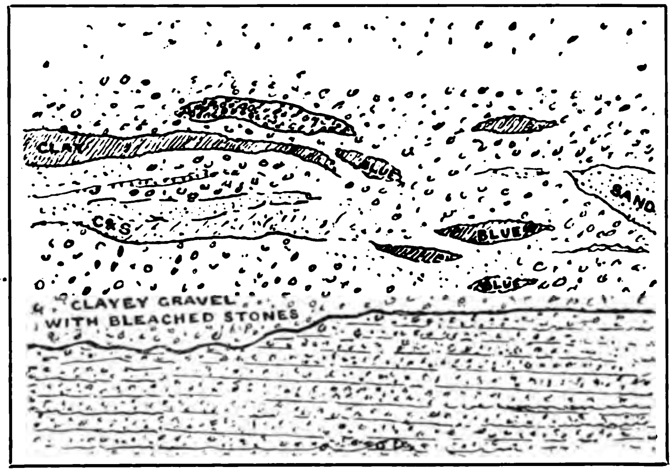
Several other furrows have been exposed in this pit, and the spaces which divided them above the stratified bed were composed of confused masses of unstratified ochreous and bleached gravel with included deposits of blue and brown clay and sand. Between the two furrows mentioned the deposits were squeezed up into archlike forms. The whole deposit has the appearance of having been torn or swept from the surface of the land to the north

A large coarsely-worked flint implement formed from a large flake much abraded was discovered at the bottom of the furrow;

it is striated with intersecting lines in the same way as stones found in the Boulder Clay on the more flattened face, and the surface of the implement, which is of the peculiar curved form found in the oldest beds, is partially decomposed by age and weathering. A smaller flat pear-shaped implement, also abraded and slightly eroded into small pittings on the surface, was found just inside the furrow, and also a small flake. There can hardly be a doubt that both implements must have been transported to lower ground by the same agency which formed and removed the other contents of the channel. If my observations and

Surface Soil. W. Surface Soil.

13 ft.



About 25 ft.

FIG. 2.—SECTION AT HANWELL (MACKLIN'S PIT), SHOWING ERODED STRATIFIED GRAVEL BENEATH UNSTRATIFIED DRIFT, WITH ENCLOSURES OF BLUE AND BROWN CLAY, SAND, BLEACHED PEBBLES, ETC.

deductions are accepted, how can man, whether he was contemporary with the Chalky Boulder Clay or not, be considered Post-Glacial in this neighbourhood? A few flint implements have also been found in the underlying stratified beds in this pit.

A particularly good example of the thick deposit of contorted unstratified drift above stratified beds has been often seen by me at Macklin's pit, Maunders Road, near the High Street, Hanwell, about a mile eastward of the excavation just described, and at rather under the 100 foot contour (see Fig. 2). The face of the excavation was rather more than 12 feet in depth, and the unstratified deposit and brick-earth above it occupied two-thirds of the upper part of the section; in some parts of this very extensive excavation

the stratified bed beneath was very distinctly eroded, the line of demarkation between the upper and lower deposits being very irregular and clearly shown. This erosion of the lower bed is often noticeable at Ealing and other districts, a remarkable instance being seen on the slope of Castlebar Hill, Ealing, at about 125 to 130 O.D., and a very early type of flint implement was discovered there. As the work was being done during the last three years at Hanwell several furrows, filled with different kinds of gravel, clay, and sand, were noticed. In a section of this pit, drawn in 1892, I saw, in unstratified gravel with enclosures of sharp green sand and bluish and brown clay, a large tabular, water-worn Tertiary Sarsen which two men could lift with difficulty, and eight feet to the north of the place where it was discovered another large piece, not quite so heavy, was met with—they had formed parts of the same block, which had been broken in Quaternary times, as shown by the old surfaces of fracture, and they fitted together. I had them conveyed to my garden, and they are now placed by the drive for the inspection of geologists.

Another large boulder of Sarsen was seen by me, in 1889, in a pit at the back of Hanwell Station; it was protruding from the base of the generally unstratified sandy and, in parts, clayey gravel. I measured the exposed portion, which was 3ft. 7in. in length, 2ft. 9in. at the widest part, and nearly 1½ft. in thickness; it was lying in fine gravel, with the coarser, contorted gravel, etc., above it; there was an appearance of cross-bedding on both sides of it, produced, no doubt, by the melting of the ice which cemented the material together into a frozen mass: at least eight feet of drift was above the Sarsen. Implements and flakes have been found in the river drift beneath it.

SOUTHALL.

Passing now to Southall, it should be noted that some large excavations have been made there during the past three or four years for gas-holders; they were deeper than is usually the case where pits are made to obtain gravel; the uneven surface of the London clay was reached at rather more than 25 feet; the same irregular structure of the upper part of the face of the excavations was generally noticeable, though there were occasional sections seen in which there was an appearance of stratification—no more, however, than frozen masses of gravel and sand would produce on the melting of the ice which bound them together.

Several teeth and the bones of *Elephas primigenius* were found in these excavations, which are at about the 100 foot contour, and about two and a half to three miles N.W. of the spot where remains of the hairy Elephant and other bones were

discovered associated with flint implements, 13 feet from the surface at Norwood Lane, and described by me.*

Among the implements found in these excavations was an implement of quartzite, very much abraded, 6½ inches in length, it is coarsely chipped and of pointed type, and has been formed from a boulder, a portion of the surface of which is left at the butt for convenient use in the hand. It must be exceedingly old from its appearance and from the position in which it was found—*i.e.*, very close to the London clay. Implements of quartzite are rare; only six or eight have, I believe, been discovered (two of which are in the collection of Sir John Evans and Mr. Llewellyn Treacher has others). A very large ochreous flint implement, 8½ inches in length, battered almost all over by contact with other stones, found 22 feet from surface, also rewarded the search of the pitmen; both of these are in my collection.

Dawley and Hayes.

The river drift is found up to the 127 contour, at the latter extending N.W. as a large sheet to the north of Hillingdon, as shown in Mr. Whitaker's elaborate memoir.

At Dawley there are very large excavations for procuring gravel and my notes thereon are numerous; it may be sufficient to say, that I have noticed in the sections, similar irregular unstratified deposits above stratified beds and also not unfrequently similar in-filled furrows, with enclosures of clay, etc., to those already described. Large quartzite and other erratic boulders are found abundantly in the lower beds, and but very rarely in the deposits above them; on one occasion I carefully examined about 10 feet of the upper part of the face in length, and did not find one "foreign" rock except very small pebbles of quartz. Some years ago a number of large flint nodules as fresh as if they had just been taken from the chalk, were found near together in the unstratified gravel; some of them measured a foot in diameter, they were in a deposit of fine gravel included in the upper part of the section.

At the excursion of the Association on the 4th May, a fine long section of unstratified deposits above bedded drift was seen extending along the northern face of the excavations in Mr. Maynard's pit.

Among the many flint implements which have been found in the pits at Dawley, there are some which should be specially mentioned, foremost among which is one of a flattened pear-shape, about 4½ by 3½ inches of Felsite or Eurite with black spots of Riebeckite, a variety of Hornblende: the rock was kindly determined for me by Mr. Lazarus Fletcher, Keeper of the mineralogical

* *Proc. Geol. Assoc.* vol. x, p. 361.

collections at the Museum of Natural History; he tells me it is very like the material of some pebbles found in Wales. It is of flattened pear shape, and chipped all over.

It is, I believe, the first implement of Felsite which has ever been found in the river drift, and why a small boulder of this rock (so rare in the drift) from which it has no doubt been formed, should have attracted the eye of Palæolithic Man, it would be hard to say. It is in my collection with others from the same pits, which are of unusual interest. One is an almost unabraded flint implement nearly unique as to its perfect form and preservation; it is $7\frac{1}{2}$ inches in length by $5\frac{1}{4}$ wide at the butt, which is worked, and is also of a flattened pear shape, and has a lustrous brown surface; the implement was discovered, with several others of less importance, in a thin bed of laminated clay, intercalated with gravel and black carbonated matter in the stratified bed about 19 to 20 feet from the surface, and near it was a large flint nodule, which the men described as like an anvil. Another is a large oval flint instrument, chipped at each end into a double bladed axe, which is remarkable as clearly showing that it was hafted with a withe or branch, bent twice round it: there are two carefully chipped depressions on one side and one on the other for the reception of the withe after the Australian method. This and many others were found during a number of years in the stratified bed, 15 to 16 feet from the surface, as were also some flakes scratched or striated on the flat side. Three well-preserved casts of *Rhynchonella* (*octoplicata?*), probably from the Lias, were discovered close together in this pit.

At a short distance west of Maynard's gravel pits at Dawley is Pipkin's pit (Fig. 3), which, though it is not now worked, still shows very strong evidence of the passage from the north of large masses of frozen gravel and clay, as well as chalky débris, in Palæolithic times.

In a measured section of about 120 feet out of about 200 feet in length seen, and about 13 feet in depth, a sketch of which with some photos was exhibited, I found, at the top, a dense brown clay or brick-earth with trail, beneath which was a very irregular deposit of chalk, rubble race, and clay, with a few stones in it, extending in tongue-like and wave-like forms into the clay—it was distinctly separated from the well-defined surface of partly stratified, and in other parts unstratified, deposits beneath containing quartz, quartzite and other erratic boulders, along the length measured, when it became mixed up and confused with contorted and lenticular deposits or enclosures of sharp sand and gravel—the underlying gravel, clayey at the upper part and very sandy lower down. The excavation did not reach, except in one place, to the regularly stratified bed, and the base of the drift was not seen. There can be no doubt whatever that the brown brick-earth had never been disturbed in recent times (specimens

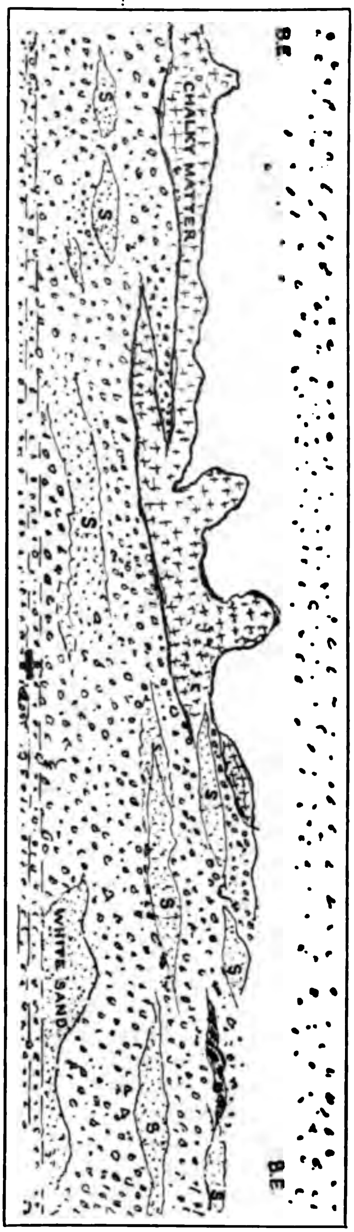


FIG. 3.—SECTION AT WEST DRAYTON (PIPKIN'S PIT), SHOWING CHALKY MATTER AND GRAVEL, WITH ENCLOSURES OF SAND, ETC.

+ A pointed implement found here.

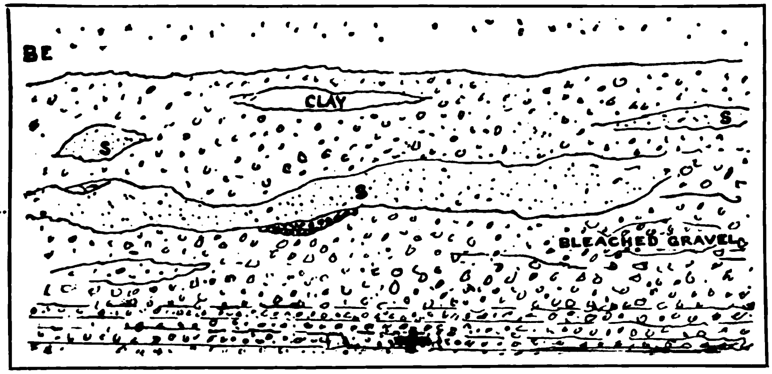
of the chalky rubble deposit were exhibited). It extends in several places to the eastern side of the pit. At the northern side, the more stratified gravel at the base is disturbed, and above it in other parts of the excavation the deposits of gravel are remarkably irregular and contorted, and contain long enclosures of sharp sand, and others of angular gravel and clay. A very perfect, yellow stained, pointed implement (now in my collection), was discovered about 13 feet from the surface, in fine sandy gravel, beneath the disordered and confused deposits above. I visited the pit soon after it was found and carefully noted the site of the find. It seems impossible to doubt that the owner of that implement lived before or during the time these deposits were formed. Nor does there appear to be any other explanation than that the confused unstratified deposits above, with their contained chalk rubble and clay, etc., were the result of the intrusion of masses of frozen material, or a minor form of morainic deposit brought by ice from higher ground, it may be, at successive periods, into the bed of the old river represented by the lower or stratified deposits beneath, indicating very cold climatic conditions in winter, and a short warm summer, when the ice which cemented such varied deposits together melted, leaving most of the masses as we find them, but sometimes allowing of their being broken up and dispersed by the flowing river. The eroded surface of the lower bed would lead to the inference that it was, for a time at least, above water, and, probably, inhabited by man, until it was again invaded by ice-borne matter or Fluvio-Glacial Drift.

West Drayton.

Near the northern banks of the canal in this district there are large and very deep excavations for gravel, they are more than 9 miles from the nearest bank of the Thames (those at Dawley 7½ miles), and their level is about 110 to 116 O.D. The sections show the same deposits of generally unstratified and contorted gravel, with enclosures of sand, very pebbly gravel, bluish and brown clay, as described in the other localities mentioned, above a stratified bed, and beneath brick-earth and trail (see Fig. 4). Occasionally the bedded gravel reaches a higher level in the sections in these pits, as if it had not been invaded to the same extent by ice-borne frozen matter. Many of the large number of flint implements found in the pits at West Drayton, as well as at Dawley, are very much abraded, and, in many cases, the angles of chipping are half obliterated. There are many others, however, in my collection from these large excavations, which have not suffered at all from rolling, while others are slightly abraded. Among the former is a large, yellow-stained, pointed, flint implement, 9 inches in length, with heavy butt, found at 14 feet from the surface. A very noticeable feature in this specimen is that it again gives us an insight into the method by which

such a large instrument was hafted, as it is much too large for use in the hand alone. Towards the butt end is a natural hollow in the crust of the nodule from which it was formed, and, corresponding to it, on the other side, is a well worked chipped depression. A design so apparent, as also seems the case of the large axe from Dawley already described, furnishes almost as positive evidence that it was used as a large pointed axe, hafted with a bent branch, as if the withe had been found with it. A very fine pointed specimen, nearly 6 inches long, with ochreous patina, may be mentioned. It was discovered 15 feet down, with many other sharply-pointed implements, unabraded, at about the same level.

Surface Soil. E. Surface Soil.



ft.

About 25 ft.

FIG. 4.—SECTION AT WEST DRAYTON (EASTWOOD'S PIT), SHOWING STRATIFIED BENEATH UNSTRATIFIED DRIFT.

B.E. Brick-earth
+ Implements found here.

A full description of the implements found in these pits would take up more space than is at my disposal, but mention should be made of a large, very rude, ochreous implement, $6\frac{1}{2}$ inches in length, formed from a coarse flake, which, like others in my collection, is very distinctly striated: the striations intersect each other and extend over the entire surface.

A number of Palæolithic implements of later age, consisting of long, sharp spear-heads, knives, etc., wrought into shape by secondary chipping, have been discovered nearer the surface than the ordinary implements formed from nodules. They are generally found at depths varying from 5 to 10 feet, and beneath the unstratified deposit. They are often nearly 6 inches in length, and are as sharp and unabraded as if they were made yesterday; they vary in colour externally and are lustrous.

As mentioned elsewhere, they probably belong to the same age as those found at the late Palæolithic workshop floor at Acton, which they greatly resemble, and may be classed with the long, flake-formed implements of the oldest cave in the Dordogne, that of Le Moustier. They are found beneath the unstratified deposit and the brick-earths, and the different depths at which they are discovered may be accounted for in the varying thickness of the unstratified or ice-borne deposit, and its absence in some sections, or the stratified beds may not have suffered so much from erosion.

The discovery of the flake-formed implements, so like the surface specimens, in different places, high up in sections, in the Thames Valley, besides the original find at Acton, is of great significance with other facts as showing the continuity of man's existence in the Valley, as I have elsewhere shown.*

UXBRIDGE AND HILLINGDON.

Northwards from West Drayton and Dawley there is a large spread of gravel and brick-earth entirely above the 100 foot contour, extending up to Harefield Lodge to the north, stretching out south-east to beyond Hayes (127 O.D.), where it is met by a large deposit of brick-earth (shown on the drift map), underlying which no doubt gravel will be found, and continuing farther east, with an irregular margin and tongues of river drift, to a lower level. On the west it extends to Denham and on the south-west to beyond Iver (Bucks). This wide extension of river drift northward to Harefield Lodge, and probably beyond, is of the highest importance in its relation to the so-called Glacial Drifts west and north of it. These deposits are intersected by the streams collectively called the Colne.

The river drifts reach the high level of about 186 O.D. at Uxbridge Common, south of which they are divided, by a narrow tract of eroded London clay, from the larger mass to be seen in the Parish gravel pits a short distance south-east of Hillingdon Church at about 177 O.D. Mr. Whitaker has so accurately yet briefly described these high-level river drifts, that it is well to quote the words in his elaborate memoir.† He says: "A spur of gravel spreads over Uxbridge Common northward to Harefield Lodge, and forms the top of the hill. This high terrace may perhaps be an outlier, separated on the south by erosion through the underlying London clay on the higher part of Uxbridge, along a line parallel to, but a little above, the High Street; the gravel has been worn away along the valley between Uxbridge and Hillingdon, to a point a little south of the road; but it again spreads northward over the higher ground to Little

* "The continuity of the Palæolithic and Neolithic Periods." *Journ. Anthrop. Inst.*, Aug. and Nov., 1892.

† *Geology of London*, 1889, vol. i, p. 393.

Hillingdon, and thence south-eastward to the brook at Yedding Green, the boundary line gradually falling to a lower level. The rectangular area of brick-earth between the last place, West End, and the canal, has a doubtful boundary. On the other side of the canal, the London clay rises from beneath; but further east a spur of gravel rises northward to Greenford, and is cut off on the east of the Brent, which river has worn its way through the London clay as far south as Hanwell, if not farther. Around Hillingdon and Hayes there is gravel, south of Uxbridge there is brick-earth as well, and at West Drayton and thence to Southall, there is a large sheet of the latter." At first sight it might appear that the high-level river drifts at Uxbridge Common, Hillingdon, and southward, may have had some relation in the past to the Colne, which flows through them, in the same sense as the Thames may be considered as the lingering relic of the larger river of Quaternary times which deposited the high-level river drift; but this suggestion does not appear to be tenable upon closer investigation, because the gravel which forms the top of the hill at Harefield Lodge, Uxbridge Common, and Hillingdon is found covering the *slope* of the hill to the east and west. It descends, as we have seen, from about 180 O.D. to 127 O.D. at Hayes and to a lower contour still further east. On the west of the Colne the same gravel is found descending the hill on that side above the 145 contour north of Denham and extending south, but divided by London clay, the result of erosion, and by patches marked "Glacial" in the drift map, from the river drift in the district of Iver.

A few other facts connected with this high-level river drift and its relation to Glacial drift may be of interest. Going north from Harefield Lodge to the village of Harefield, the Glacial deposits appear at about the 290th contour, and they are also seen to the north and north-east as well as north-west of Rickmansworth; in all instances they follow the slopes of the hills. It is a remarkable fact that the area west of the Colne marked on the map "Glacial," to which I have before alluded, descends to a *lower* level than the river drift at Uxbridge and Hillingdon, as it falls from 200 O.D. at Dromena to 156 at Love Green.

It is difficult, too, to detect any difference between the two forms of deposit either in their structure or in their constituents.

There are no sections exposed to the east of Uxbridge Common, but on the ploughed land there is abundant evidence of the character of the river drift in that locality. Some flakes, apparently from their patina Palæolithic, were found by me there; but the most remarkable feature of this gravel is the larger proportion of erratics it contains, of which a close grained diorite is most abundant, but I could find no oolitic or Oxford clay specimens. At Hillingdon, a short distance S.E. of the church, at about 177 O.D., there are extensive pits, showing, in the sections

I sketched some years ago, about 1½ feet of brick-earth with a thin seam of red gravel through it, underlying which was a confused deposit of very reddish ochreous, sub-angular flint and pebbly gravel, with slight, if any, stratification; it contains black matter and small enclosures of greyish green sand, beneath which, and divided by a horizontal black seam, is an ochreous gravel formed of larger stones with sharp sand, which appears to be horizontally bedded. In the latter, which contains many small boulders of quartz, quartzite (both the light and the purple variety), granite, and other erratics, have been discovered several flint implements, some of which are in my collection. These implements, therefore, come from the highest level at which such human relics have been found in Middlesex.

West of the road passing over Uxbridge Common there was a small excavation which was visited by me in 1893. The section

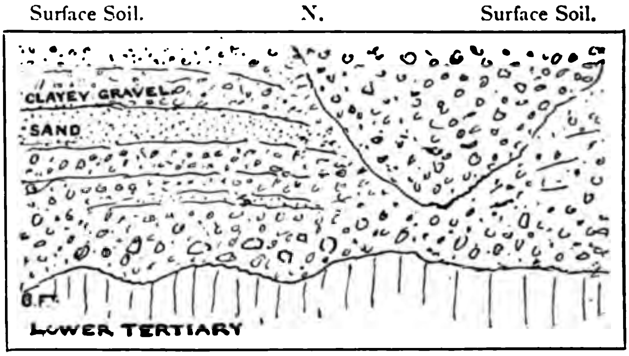


FIG. 5.—SECTION WEST OF UXBRIDGE COMMON.

(Fig. 5), drawn at the time, shows at the northern face of the pit about 8 to 9 feet of nearly horizontally bedded ochreous gravel with clayey sand at the top, beneath which was fine gravel containing flint nodules slightly abraded and small boulders of quartzite (purple and light yellow), quartz, etc. (particularly at the base), resting on the very uneven eroded lower Tertiary bed. The most remarkable feature of the section, however, was a deep furrow filled with unstratified clayey gravel, in part sub-angular, but largely composed of pebbles, many of them black, from the lower Tertiary. The furrow was 5 or 6 feet in depth, and no brick-earth was seen above it. The stratified bed was penetrated by the furrow, and the bedding was disturbed on both sides of it (see Fig. 5). We have, probably, here an example of pebbly and sub-angular gravel and sand, formerly in a frozen condition, in course of being carried down to a lower level until, as in the sections already described, it invaded the channel of the river then flowing at a lower contour.

This furrow deposit is but an example of the occurrence of

the like deposits on the lower hills to the eastward overlooking the Brent valley. They are described in my papers on the deposits at the Mount, Ealing, etc.* Since they were written, however, other striking instances of the same formation have been observed—a remarkable example being seen in sections exposed during the last three years on Castlebar Hill, 167 O.D. (Fig. 6).

In pits there dug to the depth of about eight feet, the sections showed large masses of contorted, unstratified, very pebbly gravel with included irregular deposits of blue and grey clay and sand, which extended to a lower depth than the face of the pit exhibited; a large deposit of light brown sandy clay much like boulder clay, but with no boulders or chalk in it, though containing large "islands" or patches of gravel streaked with blue

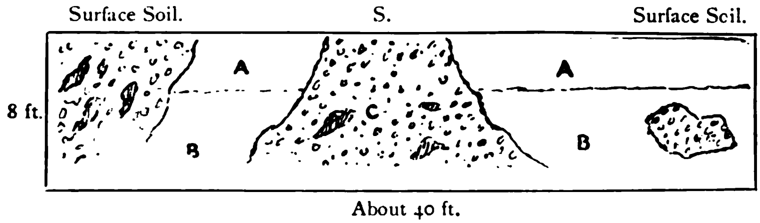


FIG. 6.—SECTION AT TOP OF CASTLEBAR HILL, 167 FEET O.D.

A. Light sandy brick-earth.
B. Dark brown brick-earth with enclosures of gravel.
C. Gravel, with enclosures of clay.

silty clay, as in section (Fig. 6). I obtained two small oolitic echinoderms from one of the pits (*Echinobrissus?*). These deposits extend down the hill to the south, near St. Stephen's Church, to within 560 yards of the known river drift at 130 O.D., with pot holes of gravel between. These irregular deposits have been probably formed by the combined action of ice and river, and may be classed as "Fluvio-Glacial." The following is my analysis of the gravel:—

Black Tertiary pebbles	12
Ochreous ditto	31
Eroded pebbles, *i.e.*, pebbles of which the surface has been in parts "eaten away" by solvents	10
Ragstone pebbles	6
Small quartz pebbles from the size of a pea to that of a mustard seed	7
Chert sub-angular	2
Very small quartzite pebble	1
Soft white pebble	1
Sub-angular flints	30
	100

* "On probable Glacial Deposits, etc., near Ealing," *Proc. Geol. Assoc.*, vol. viii., p. 173, *Palæolithic Man in N.W. Midx., etc.* (Macmillan.)

Dr. Hicks has described such in-filled furrows at Hendon, which he ascribes to the agency of ice, also on Dollis Hill, and in parts of Willesden, and he says that they passed across the valley separating Hendon from Kingsbury—he thinks the implementiferous gravel of the higher horizon should be classed as of contemporaneous age with the "Glacial" deposits at Hendon.* When the excavations were made for the tower at Wembley Hill, I noticed similar deposits of gravel, etc., in furrows about five feet deep, penetrating into the London clay beneath, and in another section unstratified gravel divided by brick-earth. The gravel was very pebbly, some of the pebbles being black, of Tertiary age, and others of a dark argillaceous rock, Ragstone and Chert—a small *Lima* (*gigantea?*) from the Lias was also found there. The limits of this paper will not allow of my giving all the evidence which points to river drift or "Fluvio-Glacial" drift having once extended above the Brent Valley, since denuded by the action of the Brent and of other small streams, and of the ancient Thames having once flowed there, perhaps as an arm or broad of the main stream. It is sufficient to say that drifts mantle the minor hills north of Ealing, as at Harlesden, where there is brick-earth and a little gravel, at Willesden (where I saw a capping from 20 to 23 feet thick of very sandy loam), and also near the entrance to Twyford Abbey (about 127 O.D.), where there was an exposure of mottled sandy loam. There is much to be said in favour of such an occurrence, which would unite the gravels descending the hill from Hillingdon, and give a more northern limit to the river drift at Hayes, Southall, and eastward to beyond Ealing.

This suggestion becomes the more probable from the fact that tusks and parts of the jaw and teeth of hippopotamus and other bones were discovered three or four years ago, embedded in a thin stratum of clayey gravel, in making the excavation for the station at Wembley Park; they were found 12 feet from the surface, and an entire tusk of hippopotamus, 15 inches long, stood out in the clay. These fossils were seen and determined by Messrs. E. T. Newton and Woodward.

IVER (BUCKS).

Returning to the west beyond West Drayton, there are large gravel pits on the banks of the "New Cut," a branch of the Grand Junction Canal, which forms the main stream near Yewsley, in which many flint instruments have been discovered, but the most interesting excavations are those belonging to the Great Western Railway Company, about a mile east of Langley Station, in the parish of Iver; the drift is here often 25 feet in thickness, and is very remarkable in structure and composition. The section is a long one, and shows contorted and disturbed gravel, etc., above stratified beds. The latter, however, sometimes reach to within

* *Quart. Journ. Geol. Soc.*, vol. xlvii (1891), p. 575.

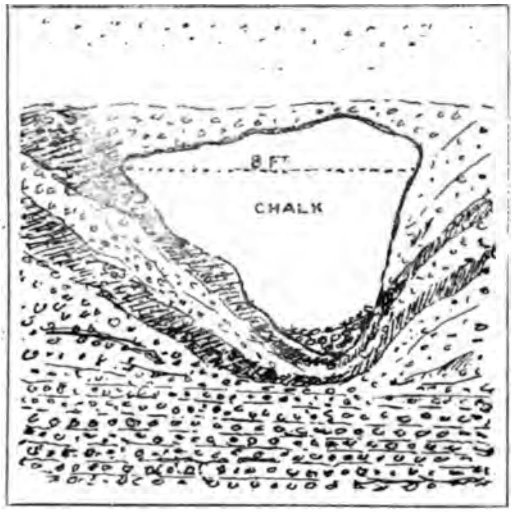


FIG. 7.—IVER PIT, GREAT WESTERN RAILWAY: SECTION SHOWING A MASS OF CHALK IN GRAVEL AND CLAY.

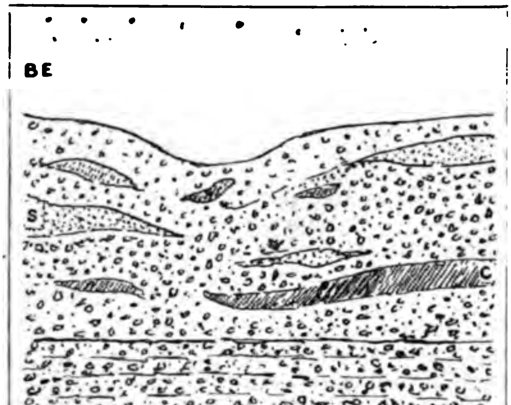


FIG. 8.—IVER PIT, GREAT WESTERN RAILWAY.
BE. Brick-earth.
S. Sand.
C. Clay.

Teeth etc., of *Elephas* were found in the unstratified drift above the bedded gravel.

6 or 7 feet of the surface, and from that level in section I obtained a series of the long, sharp, flake-formed late Palæolithic spear-heads and other implements like those already alluded to as being found at West Drayton and Dawley, and as probably corresponding in age with the "working" site at Acton.

But the most interesting discovery in these pits is that of large masses of chalk partly disintegrated, after their deposition in deep furrows, associated with sand and bluish clay in a confused mass; the jagged outline of the blocks of chalk are always distinctly visible, and they have evidently been brought there *en masse*. I have visited these pits for years, and made sections, from which I select one for description.

The section (Fig. 7) is of the northern face of the pit, and is 15 feet in depth; it shows an irregular furrow, at the bottom of which is a pocket of clayey gravel, and above it is a large mass of chalk, enclosed with light sand, clay, and gravel (specimens of which were shown at the meeting) surmounting which is brick-earth with scattered stones; around the sides and base of the furrow are seams of brown clay and sandy gravel, twisted in a remarkable manner, but still following the roughly triangular outline of the nucleus of chalk, etc., in the centre. The chalk deposit was nearly 8 feet wide at the broadest part, and 6 feet from top to bottom, and the extreme width of the furrow, or in-filled depression, was 13 feet; it penetrates nearly to the base of the section, which is here 15 feet from the surface. The stratified gravels are horizontally bedded below the furrow, but are contorted at the sides of it. The brick-earth and trail above had not been disturbed, and rested on the jagged surface of the chalk.

There have been several such furrows discovered in these excavations, two of which also contained masses of chalk, or chalk rubble; others were filled with clay of varied colour, sand, and gravel. In one of the latter (Fig. 8) a tooth and fragments of the tusks of the mammoth were discovered; this furrow, or channel, was described to me by the labourers as a long one, reaching northwards, and deepening in that direction to 12 feet. The remains appear to have been swept from the surface, and carried into the old river bed by the same agency which transported the chalk and other material.

A large number of the older forms of flint implements have been found in the lower or stratified bed, two of which now in my collection are nearly 8 inches in length; they were generally found at from 15 to 18 feet from the surface.

In my paper on the "Continuity of the Palæolithic and Neolithic Periods," I proposed a new classification of the Stone Age, *i.e.*, its division into "Eolithic, Palæolithic, Mesolithic, and Neolithic." It may be here mentioned that a splendid specimen of the Mesolithic type was discovered in the brick-earth at Iver.

I was informed by the man who found it, that it was met with at 4 feet from the surface. It is a finely-chipped, double-bladed axe, nearly $8\frac{3}{4}$ inches in length by 4 inches in width, and quite unabraded. The brick-earth throughout the districts under review is not of a homogeneous character, and it varies in thickness—in some excavations the underlying gravel even reaches the surface. There appears to be at least two kinds of deposit which are included in that term in the higher level river Drift besides "trail," which is common to both; these are a very dense brown clay and a sandy-yellow mottled loam. The latter is almost always found on the upper slopes of the hills overlooking the Brent, Colne, etc.; it is often mistaken for sandy London clay. The brown clay often contains depressions filled with sandy white loam, almost, in appearance, like a residuum of chalk.

Conclusions.

The Thames basin, in which the valley of the Thames is formed, is, in the portion under investigation in this paper, bordered to the north by hills rising to over 380 feet and isolated hills of much lesser elevation intervene between them and the Thames. There is, in fact, a general incline in the basin towards the river, and that general slope existed in early Quaternary times. There is no real barrier between the higher and lower ground, although there are undulations and lower hills, some of which appear to have escaped glaciation (Harrow, etc.), and also erosion to the extent which the present valleys manifest.

Some of the hills on the borders of the Thames basin are mantled with Glacial deposits (chalky boulder clay) as at Finchley, etc. The higher slopes of others are clothed with sub-angular and pebbly gravel, and should, in part, be referred to later stages of the ice age, while some of the highest elevations are capped by beds much older than either of these drifts, and appear to have escaped glaciation, using the word in its ordinary sense. All these facts must be taken into account in considering the glacial conditions which have once prevailed in the valley of the Thames and the relation of man thereto as an inhabitant of the valley. In the boulder clay of Middlesex and Essex (now that the old hypothesis of its deposition by icebergs is generally and very properly discarded) we have a veritable moraine formed beneath an ice-front, the extension of which was once far beyond the southern limits of the deposits as now found. When the ice-front retreated, sub-glacial conditions must have for a long period prevailed in the basin of the Thames, and the result would be many of the drifts described in this paper which mark the later and minor stages of glaciation.

As the ice-front of the chalky boulder clays receded—ice

action in some form, river and flood waters issuing very often from the retreating ice, would be the most important factors in the removal of vast quantities of matter to lower ground until they reached the bed of the river, then flowing at a very high level. Ice must, however, have played a very important part in the erosion of the valley and in the accumulation of drifts at this time. Many of these gravels reaching to the 200 foot contour and perhaps beyond that level, must be regarded, in my opinion, as terrace deposits formed under such conditions. The so-called Glacial drifts extend, as we have seen, to a lower level than what has been considered as river drift and they are alike in structure and composition, and so may also be regarded as Fluvio-Glacial. Mr. Whitaker says, "Some of these lower spreads of 'Glacial' gravel may be only very high terrace gravel."

During the successive bouts of sub-glaciation to which the Thames basin has been subjected since the deposition of the chalky boulder clay the accumulation of sub-angular and pebbly gravel and clays has been formed and transported by a modified or minor form of ice-sheet or névé to lower and still lower ground. Passing through the valleys, but leaving the higher hills of Harrow, Horsingdon, etc., uncovered, it was often eventually carried bodily, as frozen gravel gathered up in transit, into the river. Such deposits may, therefore, be regarded as a lesser form of moraine matter swept up as the névé slipped over the surface of the land, depositing it often along the banks of the river as terrace deposits. No doubt, such removals of gravel, etc., would be aided by flood streams in summer and as the subglacial conditions gradually relaxed.

It is not, however, suggested that the ice-cap, or névé, was of any great thickness, or such as is at all comparable with the confluent glacier ice, which was, probably, once spread over the midland counties, or with the tongue-like glacier ice, which left us the chalky boulder clay, with its far-travelled erratics. Looking to the general incline of the basin of the Thames towards the river, an ice-cap of comparatively small thickness would be sufficient for the purpose, and, as the unstratified gravels and furrows very rarely contain rocks foreign to the valley, but consist of sub-angular and pebbly gravel, sand, and clay, it is evident this minor glaciation was of a local character, and, probably, chiefly confined to the Thames basin. The bleached patina of the gravel which is often noticeable, indicates that it had been exposed to atmospheric conditions as a land surface, and the variability of the deposit—*i.e.*, a mass of gravel composed almost entirely of pebbles, and near to it a gathering of white, sub-angular flints (deposits of very different gravels) shows very distinctly there were different sources of supply.

In this paper I have not referred to the origin of what I believe to be the older formation, the stratified, implentiferous drift

beneath the unstratified deposits. Whether these beds were laid down by the river flowing *through* older glacial beds than those chiefly alluded to here, or whether the deposition of the older river drift, with its erratics, proceeded synchronously with the accumulation of the glacial drift, as I have endeavoured to show was the case with the deposits of the later series of fluvio-glacial drift, it would be impossible with our present knowledge to determine; but it is my conviction, based upon the discovery of implements of plateau type, and looking to the almost obliterated surface of many of the implements found in high-level gravel, and other facts, man must have lived in the Thames valley at that earlier period associated with extreme glacial conditions of climate. The bouts of glaciation since that time, no doubt, varied in intensity, and the later stages of the phenomena lasted a long time.

On the whole, whether man will be proved to have lived before the great ice-age set in or not, he was at least contemporary with the last stages of the glacial period in the valley of the Thames.

ORDINARY MEETING.

FRIDAY, 3RD MAY, 1895.

GENERAL McMAHON, F.G.S., President, in the Chair.

The donations to the Library were announced, and thanks were accorded to the several donors.

The following were elected Members of the Association: Miss Morse; Rev. George Thompson; Thomas Barron; J. T. Kemp.

A paper was read by J. ALLEN BROWN, F.G.S., on "The High-Level River-Drift between Hanwell and Iver," and was illustrated by an extensive series of specimens and flint implements.

ORDINARY MEETING.

FRIDAY, 7TH JUNE, 1895.

GENERAL McMAHON, F.G.S., President, in the Chair.

The donations to the Library were announced, and thanks were accorded to the several donors.

The following were elected Members of the Association: Geo. W. Colenutt; Miss A. Parker.

A paper was read by NICOL BROWN, F.G.S., on "The Necessity of Competent Geological Surveys of Gold Mines."

ORDINARY MEETING.

FRIDAY, 5TH JULY, 1895.

GENERAL McMAHON, F.G.S., President, in the Chair.

The donations to the Library were announced, and thanks were accorded to the several donors.

The following papers were read: "Sketch of the Geology of Co. Antrim," by ALEXANDER McHENRY, M.R.I.A.; and "The Mourne Mountains," by R. LLOYD PRAEGER, B.E., B.A.

MR. G. E. DIBLEY exhibited a complete root of *Bourgeticrinus ellipticus* from the Chalk of Northfleet, and two Ichthyosaurian vertebræ from the Gault of Burham.

EXCURSION TO GORING.

SATURDAY, 25TH MAY, 1895.

Directors: W. WHITAKER, F.R.S., AND J. H. BLAKE, F.G.S.

(*Report by* THE DIRECTORS, CHIEFLY J. H. BLAKE.)

This excursion was arranged to study the Valley of the Thames between Goring and Pangbourne.

The party, numbering about fifty, were met by the directors at the Reading railway station, at 11 a.m., then walked to Caversham Bridge, embarked on the steam-launch *Fashion*, specially engaged for the Association, and proceeded up the river, passing through the beautiful scenery of the Thames Valley, in the neighbourhood of Mapledurham, Pangbourne, etc., to Goring. An old pit, in the wood by Hart's Old Lock, was pointed out as showing the Chalk Rock, which marks the junction between Upper and Middle Chalk.

At Goring, the members disembarked, walked through the village of Streatley, noticing several large sarsens by the roadside, and then ascended the steep incline of Streatley Hill, the latter consisting for the most part of Upper Chalk capped with a small outlier of Reading Beds, and being a prolongation of the Chiltern Hills, seen on the northern side of the river. Arrived near the summit, a magnificent view was obtained, the Thames Valley from this point presenting a very gorge-like appearance; and the party, after their climb, were glad to sit here a while and listen to a dissertation by Mr. Whitaker on the denudation of this part of the Thames Valley.

He remarked that whilst it was commonly said that the escarpment was breached by the valley, it might perhaps be more correct to say that the valley was cut across by the escarpment. The former expression seems to imply that the escarpment is the older of the two, whereas there is much to be said for the view that the valley was first started more or less along the general line of dip by a transverse stream, and that the escarpment was then began by the erosion of lateral, or longitudinal tributaries. The deepening of the valley and the cutting of the escarpment would go on together afterwards.

He also remarked that, whilst on the northern side of the London Basin the main stream, the Thames, was the only one that flowed through the escarpment towards the middle part of the basin, on the southern and shorter side several streams (the Wey, the Mole, the Darent, the Medway, and the Stour) flowed

through. The difference is probably owing to the generally higher dip on the south. It is a question whether the northern streams may ever work their way back through the escarpment and tap the tract beyond.

Messrs. Blake and Leighton also spoke, and a short discussion followed. Then the members resumed their walk, passing through Common Walk on the summit of the hill, and noticing various pebbles of quartz, quartzite, lydian stone, slaty rock, etc., derived from patches of pebbly gravel (called Westleton Shingle by Prof. Prestwich) which occur on this outlier of Reading Beds. On emerging from the wood on the southern side, attention was drawn to a steep-sided valley, forming one of the side-valleys of the Thames, and its origin was discussed.

A return was now made to the launch, and the party proceeded further up the river through Goring and Cleeve Locks, with the object of seeing the "so-called" gorge from another point of view. A short distance beyond the latter lock, the return journey down the river was commenced.

Caversham Bridge was reached at about 7 p.m., where the members dispersed, the London contingent leaving Reading by the 8.15 p.m. train, and reaching Paddington at 9 p.m.

REFERENCES.

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New one-inch Ordnance Survey Map, Sheets 268 and 254.

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EXCURSION TO BANBURY, BLOXHAM, EDGE HILL AND HOOK NORTON.

WHITSUNTIDE, 1895.

Director: EDWIN A. WALFORD, F.G.S.

(*Report by* THE DIRECTOR.)

THE Association met at Banbury for the second time in the Whitsuntide of 1895. A route was planned over ground which had not before been visited.

The most complete and the most fossiliferous sections of the Middle and Upper Lias are those at Bloxham, three and a half miles south-west of Banbury, and Constitution Hill, three-quarters of a mile west of the town. It was arranged for the Saturday afternoon to go to Bloxham by rail, and to return by road by way of the Constitution Hill to the town.

In the railway cutting of Bloxham the whole of the Marlstone rock bed of the Middle Lias (zone of *Ammonites spinatus*) is shown, together with a few feet of the Marls below. Above the twenty feet of the rock-bed, but passing into it without break, is the limestone of the Upper Lias. This is succeeded by other clays and limestones (see Fig. 1, p. 178). The two lower beds of limestone of the Upper Lias contain a profusion of Ammonites, and there is also a large general molluscan fauna.

At the top of the red rock a band filled with long, cylindrical tube casts occurs, at the point of junction with the Upper Lias. These lie for the most part parallel with the bedding. At some future time they will be described. There are two phases of transition from the Middle to the Upper Lias in the Banbury district, the one where the red ferruginous limestone of the rock-bed merges into the Upper Lias, and the other where the stratum I have called the Transition Bed (really a *spina communis* zone) intervenes. With the latter phase there is evidence of attrition of the rock before the deposition of the Transition Marl, but the latter is not present at Bloxham, neither is there evidence of the Fish-bed and Paper shales, which attain a thickness of forty feet in Gloucestershire. That series may be represented in time by the thin, white limestones of the Upper Lias with *Eucyclus capitaneus*, which are really welded with, though so distinct from, the "*spinatus*" rock.

At the Transition time died much of the fauna of the preceding deposits, and then also was developed the luxuriant life of the incoming Upper Lias.

Above the second limestone bed, deposited often in hollows in it, is a thin layer, barely a half inch in thickness, made up entirely of the joints of Pentacrinites. The segments make a pavement of tesseræ which would be a good study for an Art

School. Thin and inconspicuous as the crinoidal stone is, I have traced it over the country ten miles North of Banbury, where below it are seen the Fish bed and the Transition Bed, each stored with the distinct remains of its former life. It may seem that undue value is made of the recognition of these minute zones of life, but when their extension elsewhere is considered, the supposed "hemera" here means an æon elsewhere, and the student of *regional variation* knows such labour has not been in vain.

In the Banbury district the Ammonite zones of the Upper Lias are by no means well distinguished by their special forms. *Ammonites bifrons* ranges from the lowest beds to the uppermost (*Leda ovum*), nor can its abundance at any particular stage be depended upon as a guide. *Ammonites communis* is found in all the beds below the *Leda ovum* clays, and is replaced largely, if not wholly, by *Am. Holandræi* in the Transition Bed. *Ammonites serpentinus* may hold good as a name for the Fish-bed and Paper shales.

At Constitution Hill, the succession of the beds is shown as in Fig. 2. The marls below the rock-bed are nowhere seen in their full thickness, and vary from 20 to 30 feet. The brickyard in the Green Lane, south east of the town is the best exposure. The marl belt, however, plays an important part both in the physical geology of the countryside and in its agriculture. At its base is the chief water supply of the district. It is also marked by the terraced fields of its slopes. Bands of limestone in the lower part, near Byfield, yield Ammo-

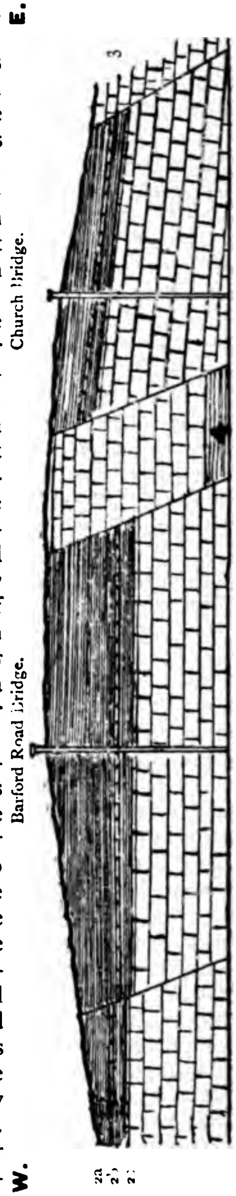

FIG. 1.—BLOXHAM RAILWAY CUTTING NEAR THE STATION.

2a. Upper Lias Clays.
2b. ,, Limestones. (Cephalopod Bed and Pentacrinitic Bed.)
2c. Upper Lias Limestone.
3. Middle Lias Marlstone.
4. ,, ,, Marls.

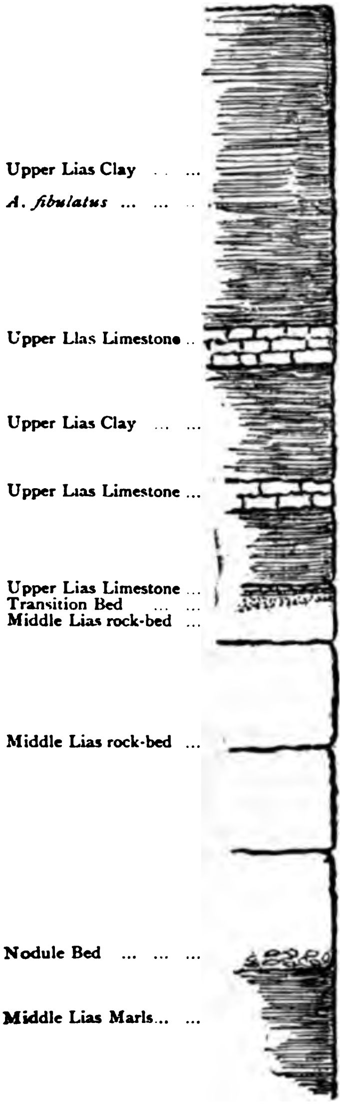

FIG. 2.—VERTICAL SECTION: MR. KIMBERLEY'S AND MR. ATTWOOD'S BRICKYARDS, CONSTITUTION HILL, BANBURY.

nites in form between *Am. spinatus* and *Am. margaritatus*, also *Am. amaltheus coronatus*, Quenst., *Trochus nitens*, Dumort., *Turbo latilabrus*, Stol., *Cardita multicostata*, Phil., and many other small molluscs. In the marls themselves *Plicatula lævigata*, Dumort., occurs, but is rare.

The rock-bed above, into which there is gradual lithological and palæontological passage, is the Marlstone of the Geological Survey and the Hornton stone of the country folk. It is the same as that of Bloxham. It is a ferruginous cyprid limestone, of which I read an extended account before the Geological Society, but the paper has not been published. Though neither of the sections seen by the members of the Association showed more than 20 feet of rock it does attain 30 feet in thickness, and at Edge Hill, visited on the Whit Monday, its maximum thickness is between 25 and 30 feet. Throughout its extent, though rarely exposed, is the nodule bed at the base, always stored with the shells of mollusca and sometimes with corals.

The Marlstone by the oxydisation of its iron is often red brown throughout. The lower courses have cores varying from grey green to dark green in colour, and make a valuable building stone. The best building stone course is the bottom rag; the top rag yields the paving stone and stone well known for domestic work. Good alike for both architectural and general building purposes, the Hornton stone (Hornton is the best source of supply) has earned an excellent local name. Though in Acland

and Ruskin's good book, "*The Oxford Museum*," "columns of slate, and shafts of lias blue and white, marbles of Purbeck, Stamford, and Buckingham" are quoted, there is no mention of, nor apparently place in the beautiful Museum for, the sober grey green Hornton stone—the best of all.

As at Bloxham, the Marlstone and the Upper Lias limestone form one course, with, however, an intervening bed of crinoidal ossicles, which represents the Transition time.

The overlying clays and limestones correlate with those of Bloxham, but yield fossils indifferently preserved, *Ammonites communis*, *Am. bifrons*, etc.

In Mr. Attwood's brickyard the higher clays extend upwards for 40 feet, and are sparingly fossiliferous. *Ammonites fibulatus* is not uncommon, and the horizon, the *Leda ovum* bed, is characterised by it more than by the presence of *Leda*. A patch of Inferior Oolite caps the whole. We have seen, then, that an almost continuous section is there shown, from the Inferior Oolite through the various zones of the Upper Lias, and through the Marlstone, to the underlying marls. The Constitution Hill was, however, visited on a following day, in consequence of a rainstorm compelling an early return of the members to headquarters.

FENNY COMPTON, BURTON DASSETT, AND EDGE HILL. (Fig. 3.)

Lower beds of the Middle Lias than any shown at Banbury (the Lower Lias of the Geological Survey) are to be seen in the railway cuttings at Fenny Compton. On the Whit Monday morning the Association began the work of the day at nine o'clock, by studying the rock ledges and clay slopes, which are but partially obscured. The section exposes from 30 to 40 feet of clays, with two thin rock courses, and an upper line of nodules. The Ammonites of the beds are *Am. Valdani*, D'Orb., *Am. Maugenesti*, D'Orb., and, more rarely, *Am. Ibex*, Quenst., and *pettos*, Quenst. Mr. H. B. Woodward, in his memoir on the Lias of England and Wales, doubts the existence of the zone of *Am. Ibex* in England. At Fenny Compton, however, it seems that the zone would be better so named than as the *Am. Jamesoni* zone of Mr. T. Beesley. The latter Ammonite is of very problematical occurrence. Fragments of *Am. Henleyi* in the higher beds complete the sequence of the Middle Lias of the Banbury district; for it is at the zone of *Am. Henleyi* that the Banbury town series breaks off. The object of the day was not to study in detail the deposits or the fauna of the Fenny Compton Lias; hence the party was soon on the way to the Dassett Hills, travelling pretty much upon the line of the section shown in Fig. 3.

Upon nearly the same level, along the crest of the Fenny Compton and Dassett Hills, can be seen the sands of the Inferior Oolite, the clays of the Upper Lias, and the red rock of the Middle Lias. At the bottom of the hills, both on the northern and on the southern sides, the red rock may also be seen. There are faults everywhere. The hills are but the wreckage of the former line of escarpment. In the Upper Lias of the old brickyard on the Fenny Compton Hill the common fossils of the cephalapoda-beds were collected, and the phase of transition from the Middle to the Upper Lias was seen to be the same as at Bloxham. The difference between the clay-covered and the uncovered rock of the Middle Lias is contrasted in two contiguous quarries. In the one the stone is red-brown, with a tendency to cannon-ball structure, by weathering; in the other, the rock is dark green, with red bands. The clay cap has saved the rock from oxydisation, by preventing the passage of water so readily through it.

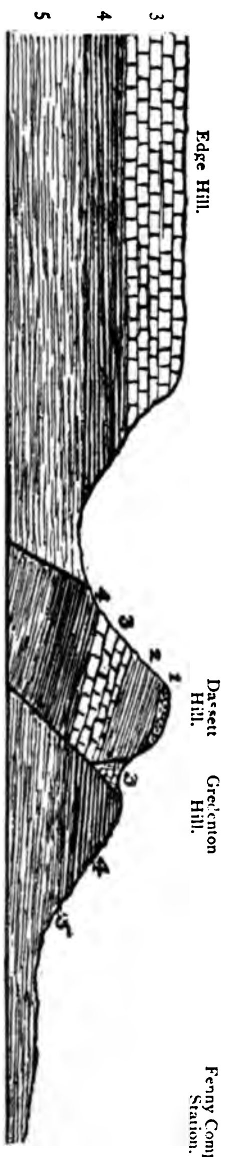

FIG. 3.—SECTION FROM EDGE HILL, THROUGH THE BURTON DASSETT HILLS TO FENNY COMPTON, WARWICKSHIRE.

1. Inferior Oolite.
2. Upper Lias.
3. Middle Lias Marlstone.
4. Middle Lias Marls.
5. " " Clays.
6. Lower Lias.

The interest of the Dassett Hills, however, centres in the sand and sandstone of the Inferior Oolite. Their resemblance to the sandy ironstones of Duston is evident, and when this is bracketed with the occurrence of casts of similar shells such as *Astarte elegans*, Sow., and *Trigoniæ*, there is no doubt of the continuance of conditions like those which made the Northampton sands of their commercial value. It is the farthest westward extension of the true Northampton

Sand, allowing that term to represent for a time the beds of sandy ironstone at the base of the Northamptonshire Inferior Oolite.

Ironstone "boxes," filled with fine white sand, as in the Northampton quarries, were found by Miss A. Parker and Mr. T. Leighton.

The connection of the Northamptonshire Inferior Oolite with the Hook Norton (Oxfordshire) type has not been clearly defined, though Professor J. W. Judd in his masterly essay on "The Geology of Rutland," and more recently Mr. H. B. Woodward in his "Lower Oolite Rocks of England" approach the mark. *Hudleston's* Nerinæa beds of the Yorkshire Dogger, Sharp's† series E of the Northamptonshire Oolites, and my series A and B of the Oxfordshire Inferior Oolite are, I consider, practically of one age.* The term Northampton Sand has been so generally used for both the upper sands and the sandy ironstone of Northamptonshire, that it has become misleading. In Oxfordshire the ten or twelve feet of limestone (A and B) represent the Northamptonshire ironstone (E); and at that part of the Dassett Hills, where the small quarry exposes the ferruginous sands, we have the representatives of Sharp's series E, with a few fossil casts to show their relationship to the lower beds of the limestone capping the hills on the borders of N.W. Oxfordshire. Whether we call the fossils which are found in Oxfordshire and Northamptonshire *Ammonites opalinus*, Rein., *Am. Murchisonæ*, Sow., *Am. insignis*, Schub., or by other names, will matter little; the forms are alike and occur on the same horizon. Study of the other fossils in my lists‡ and in Mr. S. Sharp's § lists will confirm the relationship of the strata, though it seems probable under his series E were included other beds than those characterised by the Ammonites named. I have been able to separate clearly by the fauna the superior beds of high horizon. Further consideration of the true palæontological horizon of the beds A and B of Oxfordshire must be deferred.

Descent of the North Hill, on foot, brought to view the beautiful terraced slopes of Gredenton Hill—a low spur of the main ridge. First were pointed out, on the top of the terraced hill, the Middle Lias Marls, lying alongside of, and on the same level as, the superior rock-bed of the zone of *Am. spinatus*. The fault by which the Marlstone appears to have been let down as in a trough, trends across the inner third of Gredenton Hill to the N.N.E. Several of the common fossils of the Marls were found, small as the exposure was, *Pholadomya ambigua*, Sow., *Greslya liasina*, Ag., and Ammonite forms between *Am. margaritatus* and *Am. spinatus*. The main points of terrace

* Hudleston, W. H., On the Yorkshire Oolites, *Geol. Mag.*, 1882.
† Sharp, S., On the Oolites of Northamptonshire, *Quart. Journ. Geol. Soc.*, 1870.
‡ Walford, E. A., On the so-called Northampton Sand, *Quart. Journ. Geol. Soc.*, 1883.
§ Sharp, S., On the Oolites of Northamptonshire, *Quart Journ. Geol. Soc.*, 1870.

formation were explained again, as they had been before the Northampton Natural History Society and the Oxford meeting of the British Association (1894):—

The downward creep of the surface and sub-surface soil caused by percolation of water through the beds. The line of waterflow at the base of the hill aiding by both chemical and mechanical waste the cause of downslide. To these was added the nearly constant association of faults with the terraced lands. The fact that the terraces occur always upon the line of the marls, alone gave strong evidence of their geologic origin. There was, however, even among the geologists, considerable contention for their human origin as banks of cultivation, but the occurrence elsewhere of terraces, varying from the depth of step of a few inches to that of many feet, breaks down much of the cultivation theory.

Continuing the route over the Burton Hill, the road across the plain led to Knowle End, the foot of Edge Hill. There began historic ground, for near about the line of road was Rupert's charge in the first great fight between King and Commons in 1662. Though the details of the fight were tempting to linger over, the famous quarries of Edge Hill had to be visited. The level ground extending from the Edge Hill scarp to Hornton, and again with slight dip southward, has been extensively quarried in past years. There are now but five or six quarries in work. Reference to the section (p. 181) will show the "Marlstone" covers the whole of the high ground, and there is no trace nearer than Shenloe Hill, on the W. flank, of the beds of Upper Lias once thickly capping the stone. Coombe Hill gave the following section:

COOMBE HILL QUARRY, EDGE HILL.

Middle Lias—zone *Ammonites spinatus*.

			ft.	in.
1.	Humus	. . . .	2	0
2.	Marlstone—	a red brown ferruginous limestone in shivers atop .	6	0
3.	„	Top Rag, in thin beds with green core . . .	6	0
4.	„	ochreous band . . .	0	8
5.	„	red brown stone, with top and bottom courses, blue green cores	3	6
6.	„	Lower Rag, dark green cores	3	0

(Bed 5 is the Pendle of other quarries)

It is the lower course from which is won the good building stone used over the whole of the countryside. To the palæonto-

logist there is little of importance, excepting that Hornton is the home of Sowerby's type of *Terebratula punctata*.

Continuance of the drive past Upton brought the excursionists to the point where the Edge Hill escarpment breaks into isolated hills—Shenloe Hill, Mine Hill, Epwell Hill, etc. At Shennington other good examples of terraced fields were seen in the ground called Rattlecombe Slade and the adjoining field, and with these ended the work of the day.

Hook Norton.

During the making of the Banbury Railway fourteen years since, the Association visited Chipping Norton and made also an inspection of the Hook Norton cutting, under the guidance of Messrs. Wilfrid Hudleston and T. Beesley. Since then the ironstone of the Middle Lias has been brought into notice at Hook Norton, and has been for many years successfully worked by the Hook Norton Ironstone Company. The old workings expose a face of about fifteen feet of stone, compact and green-hearted in the lower beds. In the new workings the ironstone is rotten, soft and ochreous, and the fossils therein appear as blackened casts, the whole resembling the Ironstone of the Inferior Oolite of New Duston, Northamptonshire. The nodule beds, forming the base of the stone, provided good representative gatherings of fossils; amongst them were *Am. spinatus*, Brug., *Ostrea sportella*, Dumort, *Harpax lævigatus*, d'Orb, and great specimens of *Cardinia concinna*, Sow., and *Pecten æquivalvis*, Sow.

A cutting made for the tramway showed the basement beds of the stone better than had yet been seen.

		ft.	in.
1.	"Marlstone," a sandy, ferruginous limestone, crowded with fossils, *Spirifer oxygona*, *Pecten*, several sp., *Terebratula punctata*, *T. Edwardsii* . .	3	0
2.	Hard, light brown Marl with irony concretions	1	1
3.	Marlstone, a rotten stone, with flattened nodules, containing *Ditrupa* and *Ostrea sportella*	0	6
4.	Hard marl, with ochreous parting at base	3	6
5.	Grey, sandy Shales	4	0

In the great cutting one mile south of the railway station, the Upper Lias Clays and the various beds of the Oxfordshire series of the Inferior Oolite are cut through. Fragments of the Great Oolite rest here and there in rifts and pockets of the Inferior Oolite. Much obscured as the section is by the falling in of the rock masses, the sequence can yet be made out. Though no attempt was made in the short time left at disposal to study the

beds in detail, the number of fossils collected was sufficient to denote the high horizon from which they were derived. *Trigonia producta*, Lyc., *T. angulata*, Lyc., *Lima bellula*, Lyc., *Isastræa serialis*, E. and H., *Clausantrea Conybeari*, E. and H., *Thamnastræa Defranciana*, E. and H., were some of the rarer species found.

At this point the party separated, some returning to town by way of Chipping Norton, and others to Banbury and more northern homes.

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THE MAKING OF THE DASSETT AND EDGE HILLS OF SOUTH WARWICKSHIRE.

BY EDWIN A WALFORD, F.G.S.

WHETHER we take in hand Sheet 45 N.W. of the map of the Geological Survey and scan the orange-coloured masses which project into the brown plain, or whether we stand on the hills which the orange colour represents on the map, we are brought face to face with the question of the former spread and continuity of the high land over the outspaces and interspaces now represented by vale and plain. There is no doubt that the

stone-covered land did extend far beyond its present boundaries to the north and to the north-east. To some extent this is suggested by the line of higher land (500 feet level) stretching from Napton-on-the-Hill, thirteen miles north of Banbury, to Boddington Hill, five miles nearer to the town. The rocky caps of the two hills show by their presence the former continuation of the stone not only along the ridge but over the eastern vales. From Boddington S.W. by W. to the Dassett Hills the line of watershed allows the inference of a high land ridge there. As to how much and for how far in yet more distant days that land was covered by the thick clays of the Upper Lias and the limestones of the Inferior Oolite we can feebly surmise. The shreds and patches of the rocks, sands and clays are left here and there on the hill-tops to tell the tale of their former spread. Great as the work seems to be for the small drainage power of the feeble streams and slow brooks, theirs has been the work of removal. Raindrop, streamlet, brook, and river are the widening steps of a downward way of land waste.

It will not be unsafe to assume that the main lines of drainage and the main lines of high and low land have been the same since the land took its present form. And it is probable that rocks far below the level of the deep vales are moulded to the pattern of the surface contour, so that were the present surface removed the contour of the face of the country would be mapped out in some degree upon the deeper seated strata by its flexures, folds, and slips.

The fact of the patches of the Inferior Oolite and Upper Lias being let down by faults shows the displacement to have been during the time of the greater extension of the Inferior Oolite, and it is not too much to assume that the whole of the Jurassic series once covered the present hills. This of to-day is but the skeleton of the greater land of past days. The covering was stripped long ere our time, for the remains of the stone age are strewn over our ploughed fields.

The succession of the strata forming the Edge Hills and the Dassett Hills is shown on the section, Fig. 1, of the preceding report (p. 179). Twenty to thirty feet of rock, twenty to thirty feet of slippery light-coloured marls, then blue clays, and thin limestones at the base. Rock-bed porous, marls porous, blue clays the water line. The water line is the sliding line for the heavy load of marl and rock in their downward passage. The rock is undermined by the water-flow, it squeezes downwards and outwards towards the lines of least resistance—that is, towards the vales; but in this case towards the south vales with the dip of the strata, otherwise, *i.e.*, if towards the north escarpment, the strata would have to be lifted *up hill*. In the case of the Dassett range, where the ridge is broken up into separate hills, the main flow of drainage is also southwards. Formerly, the

main vale, like the Hornton and Ratley vales, was cut off from the north by an ironstone ridge. Both by chemical solution and mechanical dissolution the porous beds are being constantly reduced. In the summer time there is drying and shrinkage. By capillary attraction, and by evaporation the water is also drawn from the depths to the surface. Thus the summer time makes the open lines of flow for the next great rainfall, and for waste along those lines.

An important, and I believe an overlooked, factor in the breaking up of rocks is the force of compressed air and the force of compressed water in underground springs in flood time. The upspringing of water in a new well and the upward rush of deep springs are evidence of this hydraulic force. Whereas frost and snow affect mainly the few feet of surface, air and water do their work at the greater depths.

Above Gredenton the hills are spilt in half; one part slides towards Dassett, another part slides towards Fenny Compton plain, and is traversed by minor faults. The making of the Dasset range may be put as the peeling of the stone beds from the top. At the top of Church Hill is a remnant of the Inferior Oolite of the true "Northampton Sand" type. It is the farthest westward touch of the true Northampton type. It yields casts of the shells *Astarte elegans*, etc., in nests, as in the Duston and other ironstone quarries around Northampton. On Fenny Compton Hill are Upper Lias limestones and shales faulted against the "Marlstone."

The altitude of the highest part of Edge Hill is 800; the level of the Marlstone at Banbury is about 540. The fall of level and the dip of the stone strata are equal, for the stone remains as a surface rock on the high lands for the eight intervening miles. Hence the main flow of drainage is with the general dip, and the greatest rock waste must be towards the greatest outflow —the low level. The mechanical waste I take to be greater where there is rapid outflow. The chemical waste is by the slower process of saturation and filtration of water through strata.

It is a safe assumption that for every rivulet and stream *upon* the surface there are twice or three times as many far *below* the surface. What distance these underground streams may flow before some intersecting valley receives their outflow and they "come to day" can be measured only by the vastness of the land.

At the foot of the Edge Hill escarpment takes place a smaller outflow, causing displacement of the rock and sliding outward of the marls, though not sufficient to break the ridge into irregular slopes like the Dasset Hills. For though the main dip of the rock bed is away from the north, there is nevertheless some slip and break down of the rock at the edge of the slope. There is not much curvature or dip of the strata *outwards*, towards the hill-front, so common in the physiography of our hilly lands.

When displaced the fall of the rock is naturally backwards. The line of outflow of water can be traced in the hummocky ground at the hill foot. It will be seen by looking again at the map how nearly the E. fork of the Horley vale has eaten its way backwards through the escarpment to Arlescot. The Warmington ridge will, when worn through, break up as the Dassett Hills have done.

The general straightness of the line of the N.W. and the N.E. fronts of Edge Hill can be accounted for only by the uniform hardness of the rock and marls of which they are made. Below, the water-flow is through the Vale of the Red Horse into the Avon and the Bristol Channel. The high land of the ridge is a watershed of the Cherwell, and hence a feeder of the Thames.

EXCURSION TO CHELMSFORD.

SATURDAY, 8TH JUNE, 1895.

Director: T. V. HOLMES, F.G.S.

(*Report by* THE DIRECTOR.)

ON leaving the railway station the party proceeded northward along the Broomfield Road, as far as the footpath on its western side, just beyond the engineering works of Mr. F. Christy. Taking this footpath, they paused at the pit in Chalky Boulder Clay in the second field entered. Mr. F. Christy, the owner of the land, had been good enough to employ a man to give a fresh surface to part of this section for the benefit of the party. Owing to the disuse of Boulder Clay as manure, there are extremely few good, that is clear, sections in it. Some peaty material at one corner of this pit attracted some attention. There seemed to be no reason, however, for regarding it as of Glacial age, though the section where it appeared was obscure, and threw no light on the question. For, in the Boulder Clay area we traversed, we found that old excavations were very numerous, and might be seen in almost every field, though the pits had usually become converted into ponds teeming with aquatic plants. Doubtless a portion of the pit we visited had once been a pond, which had been filled up as the excavation had been extended in another direction. The Boulder Clay had evidently been worked most recently in the most westerly part of the pit, or, in other words, in that most remote, both from the peaty material and from the footpath.

While in this pit the Director, spreading upon the ground the maps of the Geological Survey showing the surrounding districts of Essex, pointed out that from Chelmsford northward the surface consisted mainly of Boulder Clay, the underlying Glacial Gravel and the still older London Clay appearing chiefly in the valleys of the various streams. The thickness of the Glacial Drift Beds varied very much. In one spot a well might show 8 or 10 feet of Boulder Clay above 30 or 40 feet of Gravel; in another

the proportions might be reversed. Occasionally their combined thickness exceeded 100 feet.

Leaving the pit, the party walked through the old pottery at the north-east corner of the same field, where, though there were no clear sections, the heaps of material that had been sifted out were of some interest to the geologist, though they had been useless to the potter. They then made their way, under the guidance of Mr. Miller Christy, to the road between Patching Hall and Scot's Green. There a well was being sunk, close to the road, for the better supply of some cottages, the inhabitants of which had been using the water from some ponds, which had once been marl pits, close by. The characteristics of the Chalky Boulder Clay were extremely well shown in the lumps which had been thrown out of this well.

Mr. Miller Christy then led the way to his residence, known as Priors, where he had kindly invited the party to partake of tea, and the great heat of the day made the rest and refreshment unusually welcome. After tea the Director read some notes on the geological character of the land that had gone out of cultivation in the Ongar, Chelmsford, Maldon, and Braintree districts of Essex. These notes had been kindly sent him by Mr. H. W. Monckton, who was unable to be present. Mr. Monckton remarked:

"The report on the Ongar, Chelmsford, Maldon, and Braintree districts of Essex, by Mr. Hunter Pringle, published as a Blue Book, was largely referred to in the House of Commons during the debate on agricultural depression on July 11th, 1894.

"The map attached to it is of special interest to dwellers in south-east Essex. On it the fields which are alleged to have gone out of cultivation since 1880 are marked as black patches.

"To one acquainted with the district, it is apparent at a glance that the black patches are mainly at places where the London Clay forms the surface of the ground.

"At the north-east corner of the map there is a tract covered with Chalky Boulder Clay quite free from black patches.

"Between Chelmsford and Maldon there is a considerable extent of gravel and alluvium, and on it there are not many black patches excepting in places where the gravel is thin, and the London Clay which underlies it is near the surface.

"There is a small, black patch on Bagshot Sand and Boulder Clay at Frierning, and one on gravel on the hillside between that place and Ingatestone. And between Woodham Ferris and Bicknacre Priory there are several black patches on Boulder Clay and loamy gravel.

"South of Woodham Ferris there is a large black patch on the alluvium of Woodham Marsh, and there is another on the alluvium of Hadleigh Marsh. All those south of the railway from Pitsea to Benfleet are on alluvium.

"At the eastern end of the map there are some black patches

on gravel and alluvium. Near Hadleigh there is one on Bagshots, and there is one near Mucking on various formations; but with these exceptions the black patches are on London Clay."

Mr. Monckton noted, in addition, an extraordinary statement in paragraph 10, p. 36, of Mr. H. Pringle's Report, as follows:

"The soil of Essex, with the exception of two small patches, is geologically classed as London Clay."

Surely the author of this Report should have known of the existence of the Drift Maps of the Geological Survey. The latest published, that of Sheet 47, appeared in 1885, the others earlier. And the Drift Maps show that north of a line drawn from east to west through Chelmsford the London Clay, where it exists, occupies but a very small proportion of the surface. While, as its outcrop, against the Glacial Drift, is along a line from Bishop Stortford to Sudbury, it is not to be found, either at or below the surface, over a good many square miles of north-western Essex.

The party then left Priors in the direction of Writtle Wick, accompanied by Mr. Miller Christy, who pointed out a sarsen stone of considerable size at the entrance to the grounds of Mr. Rosling's house, between 300 and 400 yards north of the pit in Glacial Gravel at Writtle Wick, from which it had been derived. We were informed by Miss Rosling that it had been found at a depth of about 2 feet beneath the surface. Possibly at one time it may have been a "standing-stone." Some discussion here took place about the origin of the name *sarsen*. One member objected to a derivation from *Saracen*, on the ground that the old stone circles, etc., of Britain were of much earlier date than that of Mahomet and his earliest followers. This is, of course, true; but we have no record or tradition of the name given to these stone monuments by their makers. On the other hand, a correspondent of *Notes and Queries*, vol. xi, p. 494 (June 23rd, 1855), points out that the Saxons applied the term *Saresyn* to pagans or heathen in general, and consequently that the ancient stone circles and standing-stones naturally became known as Saresyn (or heathen) stones. Also that the term Saresyn was applied by the Saxons to the Danes, or Northmen, before they became Christians. As an example he gives the following: "Thus Robert Recart (quoted in Roberts' *History of Lyme*) says, *Duke Rollolefort was a Saresyn come out of Denmark into France.*" And the tendency of the folk-speech of a much later date to identify not merely heathenish belief, but even the Devil himself with Mahomet, is conclusively demonstrated in Burns' well-known song:

> "The De'il cam fiddling thro' the toun,
> And danc'd awa' wi' the Exciseman;
> And ilka wife cries, Auld Mahoun,
> I wish you luck of the prize, man!"

The derivation of *Sarsen* from *Saresyn* can hardly, therefore, be considered improbable or "far-fetched."

From Writtle Wick the party made its way to Chelmsford Railway Station, time not permitting a visit to the pits in Glacial Gravel, at Writtle, or to the Brickearth sections in which the jaw of the Mammoth was discovered last year.

The Director has pleasure in acknowledging the services rendered by Mr. W. Cole, Hon. Sec. Essex Field Club, and by Mr. H. Mothersole, for information respecting the sections of the district, etc.

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EXCURSION TO TILBURSTOW HILL.

SATURDAY, 15TH JUNE, 1895.

Director: THOS. LEIGHTON, F.G.S.

(*Report by* THE DIRECTOR.)

THE object of this excursion was to examine the geology of the eastern portion of the district recently described by the director in a paper read before the Geological Society.* In this paper the author stated that he had been unable to place the sections exposed at the north of the Tilburstow Hill district in the succession of beds made out a few miles to the west, whilst in the programme issued for this excursion,† it was further stated that the director had now an opinion to offer on the subject.

Full details of the various sections visited on this occasion in the neighbourhood of Tilburstow Hill, will be found in the paper referred to above, published by the Geological Society. The director stated that he had now arrived at the conclusion, both upon stratigraphical and lithological evidence, that the beds exposed in the three large pits of the Tilburstow Hill Plantation (north of the high road), were approximately on the horizon of Meÿer's Folkestone Stone-Beds of the Redhill district (*i.e.*, "Stone-Beds and Fullers' Earth" of Fig. 4 of the table appended to the author's paper already referred to.) In the Redhill district, the Geological Survey places these beds in its "Sandgate" division, but in the neighbourhood of Tilburstow Hill Plantation, the official information of both map and memoir is too meagre for identification. The present writer's Local Group No. 1, has the beds in question for its upper members in both districts.

Stratigraphical Evidence.—The level and dip of the massive chert beds exposed behind Rabbitsheath Cottages are not incompatible with their passage under the beds exposed in the three pits to the north. The Fullers' Earth has been admitted by

* *Quart. Journ. Geol. Soc.*, vol. li, 1895.
† *Circular*, dated 17th May, 1895.

all geologists to lie in basins, not mathematically on the same horizon, but always *about* the same horizon ; hence the presence of Fullers' Earth above the massive cherts of the "Fault Pit," near the Roman Road, *may* be of no stratigraphical importance. Likewise, the presence of thick Fullers' Earth above the calcareous beds in the Plantation Pits, whilst at Nutfield the thick Fullers' Earth lies below similar beds, cannot be taken as an argument against the two series of beds (Fullers' Earth and "associated rocks") lying on the same horizon.

Lithological Evidence.—The correct horizon of the beds of the Plantation Pits becomes clearer, however, when the nature of the rocks associated with the Fullers' Earth, exclusive of the blue stone, is examined. The beds described by the present writer as "Calcareous clayey greensand"* will be found to bear a strong family likeness to the twenty-six feet of "Stone-beds" at Nutfield, mentioned on page 114 of the same paper, *whilst similar beds are found nowhere else in this part of the series*, certainly not in any part of the underlying chert beds. It has also to be remembered that both at Nutfield and Tilburstow Hill the iron-sands of the Folkestone Beds follow upon the series under discussion.

Dr. G. J. Hinde stated that he believed the chert of the Plantation Pits, described by the director as "blue stone," to be the same as that seen behind Rabbitsheath Cottages and in the "Fault Pit" near the Roman Road, the difference in the chert seen in the first and two other exposures being due to weathering.

The director stated that he had, following Dr. Hinde,† favoured that view when writing his paper, there were some stratigraphical points which supported it. However, he considered that the absence of what he had described as the "associated rocks" from the two last-named exposures, rendered his present explanation, viz., that the Plantation Pits displayed a slightly higher horizon, the more acceptable.

It should be noticed that should the view favoured by Dr. Hinde eventually turn out to be the correct one, the writer's present explanation of the *succession of beds* at Tilburstow Hill will remain unaltered, but the thickness of the cherty series will be slightly reduced.

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* *Op. cit.*, p. 117.
† *Phil. Trans.*, 1885.

EXCURSION TO TOTTERNHOE.

SATURDAY, 22ND JUNE, 1895.

Director: W. HILL, F.G.S.

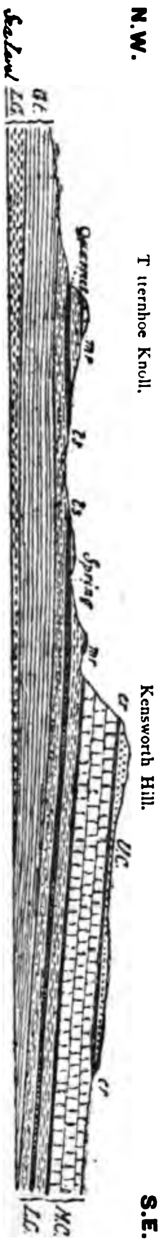
(*Report by* THE DIRECTOR).

A FAIR muster of members met the Director at the London and North Western railway station at Dunstable, and proceeded over the Downs to the large quarries of Messrs. Forder & Co., where a fine section in the Grey Chalk was inspected.

The party next walked to the old quarries of the Totternhoe Stone. These consist of galleries tunnelled under the hill, and some have undoubtedly penetrated for a considerable distance.

There appears to be no history to these quarries, but they must have been worked almost as early as, perhaps even before, the Norman Conquest, and the stone was certainly in request in early days both for interior and exterior decorative work. Dunstable Parish Church may be mentioned as an example of this, and a fragment of ornamental work from the interior of Durham Cathedral, recently submitted to the writer for examination, proved to be of this stone.

Although worked within living memory, the tunnels are, for the most part, closed by fallen débris, and their entrances grassed over, with the exception of one which was re-opened last winter by Messrs. de Beringer & Co., owners of the large quarries at Totternhoe. Permission to enter was courteously given, and



SECTION THROUGH TOTTERNHOE KNOLL AND KENSWORTH HILL, NEAR DUNSTABLE.

Horizontal Scale: 1 inch = 1 mile. Vertical Scale: 1 inch = 1,320 ft. (¼ mile).

U.C. Upper Chalk. *M.C.* Middle Chalk. *L.C.* Lower Chalk. *L.G.* Lower Greensand. *cr.* Chalk Rock. *mr.* Melbourn Rock. *ts.* Totternhoe Stone.

men with lamps conducted those who desired to examine the subterranean workings. The tunnel penetrated about 110 yards into the hill in a direct line, and there were many ramifications. The aboveground quarries of the Totternhoe Stone were next inspected, and some good examples of the stone already squared for building purposes were seen. Messrs. de Beringer & Co., by means of a trial shaft have proved the bed of Totternhoe stone to be at least 32 feet thick at this point, and blocks equal in quality for building purposes to those seen in the pit were obtained at the bottom of their shaft. These quarries were found interesting to the fossil collector, and many specimens were secured.

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1886. HILL, W., and JUKES BROWNE, A. J.—"The Melbourn Rock. . . . . from Cambridge to the Chiltern Hills." *Quart. Journ. Geol. Soc.*, vol. xlii.

EXCURSION TO BURHAM AND AYLESFORD.

SATURDAY, 29TH JUNE, 1895.

Directors: C. BIRD, B.A., F.G.S., AND W. F. HUME, D.Sc., F.G.S.

(*Report by* THE DIRECTORS.)

THE party left Cannon Street (S.E.R.), at 9.28 a.m., for Aylesford, arriving at 11.20 a.m. A start was immediately made for the Ragstone pit at the back of Preston Hall. The ragstone heaped on the road near the station was examined, a large number of fossils being obtained. These included a good-sized *Nautilus*, and blocks full of the casts of *Trigonia*. At the Preston Hill pit itself, the members were able to examine the *Trigonia*-bearing rock *in situ*, and Mr. Bird explained the distribution of the chert bands in this locality. Those who had previously visited the Hythe Beds in the Tilburstow Hill section, noticed the small thickness of the chert here compared with the enormous development of the same in the latter locality.

A second pit was visited in which the same beds were developed, and a collection of fossils was inspected, which included some large examples of *Nautilus* and *Pleurotomaria*. Flint implements have been found in the gravel beds overlying the Hythe Beds at this point.

Advancing northward, the party arrived at the sand-pit near Aylesford village. The beautiful white sand here quarried belongs to the Folkestone series, but in its upper layers becomes coloured of a dull red tint, owing to the presence of hydrous oxides of iron. Especial interest attaches to the gravel which uncomformably overlies the Aylesford sands. In this numerous remains of *Elephas primigenius* (Mammoth) have been obtained. The manager exhibited a large mandible and portion of tusks, specimens of flint implements manufactured by the notorious Flint Jack, and fragments of pottery which have aroused much interest among archæologists. Two members in advance of the main party were present at the removal of a mammoth molar from the gravels.

Proceeding to the Burham chalk-pit, a general explanation was given of the position of the Chalk zones, the *Belemnitella plena* zone being well marked as a yellowish band near the top of the lower pit. The upper pit was first visited, and the different character of the various zone members was pointed out. Thus, the nodular character of the *Inoceramus labiatus* zone, the bluish fine-grained chalk of the *Terebratulina gracilis* zone, and the nodular flint-bearing Chalk Rock were inspected. A fair collection of Middle Chalk fossils was made here, including *Spondylus spinosus*, *Echinoconus sub-rotundus*, *Terebratula semiglobosa*, and a large specimen of the type form *Terebratulina gracilis*. Teeth of *Ptychodus*, and other fish remains, as well as a small sponge, *Plocoscyphia*, had been previously obtained here by members of the party.

In the lower pit the marly layer of the *Bel. plena* zone, which previously formed a well-marked platform, had been cut back, only one member descending to the ledge still remaining to examine the yellowish marl characterising the zone at this point. It was impossible, under the circumstances, to closely study the *Inoc. labiatus* zone above, in which *Inoc. labiatus* and *Rhynchonella Cuvieri* are fairly abundant.

Time forbade a close inspection of the Lower Chalk, but in a Gault-pit near by, the junction of the Chalk Marl and Gault was displayed without the intervention of the Upper Greensand. The yellow tints due to the weathering out of ferruginous products was well shown, and Mr. Dibley exhibited a fine *Ichthyosaurus*-tooth obtained from the locality.

A pleasant tea-party at Snodland closed the day's proceedings.

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EXCURSION TO THE KENTISH PLATEAU.

SATURDAY, 13TH JULY, 1895.

Director: W. J. LEWIS ABBOTT, F.G.S.

(*Report by* THE DIRECTOR.)

THE members from London met the Director at Eynsford Station, whence they moved in a northward direction through the village, casually observing the curious old church and some of the relics which have been found near it. At the corner of a lane opposite the paper mills, a halt was made, and the Director gave a short outline of the history of the river Darenth, in the valley of which they then stood.

He pointed out how the composition of a gravel showed the nature of the rocks over which the river which formed the deposit had flowed, while the conditions of the component pebbles showed the treatment they had undergone, and thus served as a gauge for the distance they had travelled. The rock immediately under them was the Chalk, which from its northern dip was succeeded at the surface farther south, beyond its present escarpment, by the Gault, the Folkestone beds with their car-stone, and the Hythe beds with their chert and rag. Obviously a gravel made of the relics of these beds in an angular condition must have been laid down by a river which flowed over these rocks. So that when they ascended the valley slopes and reached the plateau, and found gravel of Lower Greensand composition, it would become evident that the deposit was laid down by rivers which had flowed from the south. As, however, these Lower Greensand beds were now cut off by the Holmesdale valley, which formed the Chalk escarpment, it followed that the original streams which brought down this southern material must have anteceded the formation of the Holmesdale and tributary valleys. To correctly estimate the age of these old plateau deposits it was necessary to remember the age of those of the Holmesdale Valley.

It has been shown by the discoveries of Messrs. Harrison and Abbott that the Holmesdale and Shode Valleys had been excavated to within less than a hundred feet of their present level before the Arctic conditions and heretofore considered oldest palæolithic men had passed away. That these old palæolithic deposits were *in situ* was absolutely certain from the completeness of the series found at various altitudes on the counterscarp. If we realise that the plateau deposits lay some four to five hundred feet above these, we should have to draw largely upon the bank of Geologic time. It was true a number of alarmists and well-meaning, over-cautious people have circulated evil reports to prejudice man's credit upon the bank of time, but he (the speaker) hoped to introduce them that afternoon to a security who would

stand responsible up to "preglacial" or, in other words, Pliocene time.

In passing up the lane opposite the paper mill, the composition of the gravel was examined, and its chert and ironstone noted. Next the dry valleys of the Chalk were passed over, and the difference of the nature of their flint gravels compared with those belonging to the older Darenth and plateau deposits pointed out. Climbing the heights to the unwasted conditions of Brand's Hatch, the old plateau deposit was come upon *in situ*. This is only a small field, but the dark ochreous staining of the flints and southern material forms a marked contrast to the white gravel walked over for the last two miles. Here everyone was soon engaged in pacing over the field and picking up resemblances to human work. Naturally the greater part of the members found nothing which could be regarded as man's chipping, but several were more fortunate. The field adjoining is only a few feet lower, and once formed the bank of the Fawkham river (now dry); the latter, however, in its early stages cut through the old plateau deposit, which is here absent, and the plateau types of implements are replaced by the older river forms.

The Fawkham Valley was now crossed to the village below, where refreshments were had, and rare and interesting plants secured *en route* shown round; several of which were new even to some of the botanists present. The attractions of the first part of the journey being so many, it became evident that a visit to the Stanstead pit was too much for a half-day excursion, so that the party here separated, some returning *via* Fawkham and others *via* Wrotham. Some of the latter had the opportunity of passing over Stanstead and obtained a good idea of the lie of these old plateau deposits.

In the early part of the year a pit, or rather a series of pits, was sunk on Parsonage Farm, Stanstead, which showed a remarkable succession of beds as developed upon the plateau. The order was as follows:

Two and a-half feet of sandy soil and pebbles; in the upper part neoliths were found as well as derived forms from older beds.

Three and a-half feet grey and iron-stained loam and clayey sand, no neoliths, but several good palæoliths; several pieces of southern rocks, including one boulder of Kentish Rag which appears to be deeply scored and striated.

At the base of these there was a remarkable iron pan of gravel which required a pickaxe to break it. When broken up and washed this was found to contain a goodly number of well-marked plateau implements, usually very sharp as though they had not been moved very far, while a large number of flakes showed an altogether different state of affairs to that found anywhere else on the plateau, suggesting the idea of an old plateau floor. There was a good deal of manganese in the pan, and here

and there botryoidal, slightly iridescent allophane. The pan was succeeded by a fine hard-worn gravel, in a free sandy matrix, the flints were highly bleached, decomposed, and often as soft as chalk; a condition characteristic of Lenham beds, from which they were in all probability derived. Some 20 feet of marly micaceous sand was next passed through, probably Thanet beds, without reaching the Chalk. As the Chalk comes to the surface in the adjoining field, it is fairly certain that we have here an old river channel of plateau deposit age, which is confirmed by the fact that in the denudation of this part of the country, this old channel has been cut into, and it is in these places that the plateau implements have been found. The interesting works of man thus became, not mere surface finds of no chronological value, but fossils of a particular age and horizon, which are found like all other relics of the past, both *in situ* and in derived formations.

REFERENCES.

Geological Survey Map, Sheet 6.

1872. WHITAKER. W.—"The Geology of the London Basin." *Mem. Geol. Survey*, vol. iv.
1875. TOPLEY, W.—"The Geology of the Weald." *Mem. Geol. Survey*.
For previous visits to the locality see "Record of Excursions," pp. 33—38, and *Proc. Geol. Assoc.*, vol. xiii., 1893.

EXCURSION TO TUNBRIDGE WELLS.

SATURDAY, 20TH JULY, 1895.

Directors: R. S. HERRIES, F.G.S., AND G. ABBOTT, M.R.C.S.

(*Report by* THE DIRECTORS.)

OWING to the wet weather a very small party came down with Mr. Herries by the 1.42 train from Cannon Street. At Tunbridge Wells Mr. Abbott met them at the railway station, and those who came were rewarded, as the afternoon fortunately turned out fine.

The party ascended Mount Ephraim and proceeded to the Boyne Park Estate, through which several new roads have recently been cut. On the highest part of the hill one of the numerous small outliers of Weald Clay, which cap the Tunbridge Wells Sand hereabouts, was noticed. The new road-sections showed Tunbridge Wells Sand, with the upper part quite decolourised in places, obviously by infiltration from above. The result is a very fine white sand bounded by a thin black line of carbonaceous matter. That these beds of white sand are not mere surface drift is certain, at any rate in some places, as the lines of bedding can be traced right through them from the unaltered Tunbridge Wells Sand on either side. Mr. Abbott propounded the following theory as his explanation of these appearances: "Microbes in the soil or subsoil produce an iron solvent which is carried through

the sandstone by rain water, gradually removing the oxide of iron from the grains of quartz.

"As the action proceeds the sandstone nearest the soil becomes, through the loss of its ferruginous cement, a loose white sand along which a great part of the rain finds its way. This white sand layer is also seen as pockets wherever there has been an easy route for infiltration.

"Immediately below the sand bed and closely following its irregular contour is a black band, 2 or 3 inches thick ; the blackness being due, probably, to the sand bed allowing carbonaceous particles to pass through it from the soil above.

"A portion of the rain water passes downwards and carries the solvent through the underlying rock, altering it first to a mottled yellow and white bed and ultimately to a pure white soft sandstone, which hardens on exposure. Curving black bands or circles which exist on the rocks on Tunbridge Wells and other Commons show that this process of decolourisation has gone on in them ; the soil and sand having long since been removed. The solvent acts also on the iron in the Clay Beds. Sections of clay in which the process has gone on show branching white lines which in places extend downwards eight or more feet.

"Tunbridge Wells chalybeate springs are the result of the action of iron solvent microbes growing in the soil. The honeycomb patches on the sloping surfaces of the rocks is probably due to the same cause."

The discussion centred round the cause of the black band, and as an alternative theory it was suggested that it might be due to malic and other organic acids derived from vegetable decomposition coming in contact with the sandstone bed containing iron. Nothing, however, could be decided on the spot, and further chemical testing would be required to settle the question.

The party then proceeded along Mount Ephraim and Tunbridge Wells Common, noting the remarkable rock masses, and the Directors explained that these were due to the hardening of the upper part of the Tunbridge Wells Sand. On several of these rock masses patches of white sand with black rings round them were noticed, and Mr. Abbott pointed to them as a confirmation of his theory before-mentioned. Attention was also drawn to the curious reticulation or honey-comb structure on the face of the rocks. On reaching Rusthall Common the well-known rocks here were inspected, including the "Toad Rock" and other remarkable forms. These, like many of the rocks on Tunbridge Wells Common, are undercut in a remarkable way, the Toad Rock especially consisting of a large isolated block on a small, more or less rounded, pedestal. Mr. Herries mentioned that Mr. Topley had suggested the possibility of this being due to the action of wind, using the loose sand at the base of the rocks as a file, a view advocated by Sir A. Ramsay with regard to

certain rocks of a similar character in Derbyshire; and though the sand itself is fine in character, there are numerous layers of small pebbles which would supply a sufficiently coarse material to produce such action. This was held by Dr. Abbott as only partially satisfactory, and he thought that the action of wind-blown sand was aided by the more laminated structure of the sandstone forming the pedestal on which the Toad rests. There is another outlier of Weald Clay at the highest part of the hill here, and from this spot the chief features of the view were pointed out. To the north was the long and well-marked escarpment of the Lower Greensand, while nearer was the lower line of the Bidborough Ridge; to the south the range of the Ashdown Sand was seen with its two culminating points of Crowborough Beacon and Saxonbury Hill.

The party then crossed the Happy Valley to the High Rocks. At the bottom of the valley is a patch mapped Wadhurst Clay, and some clay was seen at the side of the stream. Nearer the High Rocks the rock of the Tunbridge Wells Sand appears abruptly just N. of the road owing to a fault which runs in a north and south direction, east of the High Rocks, and then bends to the north-west, thus bringing the Wadhurst Clay against the Tunbridge Wells Sands at this point. Owing to the inaccuracy of the old Ordnance Map the geological mapping is a little difficult to follow. At the High Rocks the rock masses were again seen, on a larger scale than those on the other side of the valley, and the peculiar straight-sided fissures between them were remarked.

At the top is another patch of Weald Clay, which is cut off on the east by the fault already mentioned. Tea was obtained at the High Rocks Hotel, and the party returned to Tunbridge Wells in time for the 8.5 train to Cannon Street.

REFERENCES.

Geological Survey Map, Sheet 6.

1875. TOPLEY, W.—"The Geology of the Weald." *Mem. Geol. Survey.*
For previous visits to the locality, see *Record of Excursions*, pp. 38-44.

LONG EXCURSION TO BELFAST, THE COAST OF ANTRIM, AND THE MOURNE MOUNTAINS.

MONDAY, 29TH JULY, TO SATURDAY, 3RD AUGUST, 1895.

Director: A. MCHENRY, M.R.I.A., GEOLOGICAL SURVEY OF IRELAND.

(*Report by* R. S. HERRIES; *revised by* THE DIRECTOR.)

THIS excursion was the outcome of an invitation to visit Belfast, given by the Belfast Naturalists' Field Club to the Association during their visit to Dublin and Wicklow in 1893. The Field Club, to a great extent, undertook the somewhat difficult arrangements necessary for the accommodation and

transport of the members of the Association during their drive round the coast; and it was to the excellence of these arrangements that the success of the excursion was largely due. The thanks of the Association in this respect are particularly due to Miss S. M. Thompson and Mr. F. J. Bigger, the honorary secretaries of the Field Club; and this opportunity may be taken of thanking those gentlemen, such as Mr. R. Lloyd Praeger of Dublin, Messrs. R. Welch and W. Gray of Belfast, and Mr. W. A. Traill, C.E., of Bushmills, who accompanied the party on various days, and were always ready to impart all the information in their power about the sections visited to any members of the Association that asked for it.

For the first two days the headquarters of the Association were at the Shaftesbury Hotel, Belfast, and here the members assembled at various times and by various routes. For the early arrivals, a preliminary excursion was arranged to Scrabo Hill, near Newtownards, to which place the party proceeded by train. This hill is between Belfast and Strangford Loughs, and consists of Trias, Keuper above and Bunter below, capped by basalt, and penetrated by numerous dykes of the same material, both vertical and horizontal. Good examples of ripple-marks, rain-pittings, etc., were seen on the fallen blocks of sandstone, and the spheroidal structure of the basalt capping was noticed.

On *Monday, 29th July*, the party started about 11 o'clock to drive to Cave Hill Quarry. Here they found the Chalk overlain by basalt, and resting on Upper Greensand, beneath which again at one end of the quarry the Lias Clays were seen. The Director explained that the Chalk here, as elsewhere in Antrim, was Upper Chalk, while the Lias was Lower Lias. Several specimens of *Belemnitella mucronata* were obtained from the Chalk, but the Lias was not in a good state for fossil collecting. The basalt here, which is not columnar, but somewhat coarse in texture and full of amygdaloidal cavities, belongs to the Lower Basaltic Sheet,* which spread over a large part of the county of Antrim as the result of great volcanic activity in Eocene times. The Chalk was much altered and hardened by the contact of the basalt, and this is apparent several feet from its upper surface, although the Director said that he did not attribute its hard and compact nature entirely to this cause. At one end of the quarry, later dykes of basalt were seen traversing the Chalk and the basalt sheet above. Cave Hill was then ascended, and a very fine view was obtained, including Belfast and Strangford Loughs. Lough Neagh, the Mourne Mountains, and the Scottish coast, Coming down the north side of the hill, the Whitewell Quarries were visited, where the Chalk and overlying basalt were again

* See "Sketch of the Geology of County Antrim," by A. McHenry, *Proc. Geol. Assoc.*, vol. xiv, p. 129 (at p. 138). The references in the text throughout this account are to this paper, or to that on "The Mourne Mountains," by R. Lloyd Praeger, B.E., B.A., *loc. cit.*, p. 148.

seen. Here the amygdaloidal cavities in the latter were found to be filled with several varieties of zeolites, the pretty needle-like crystals of which were much admired. The carriages were now rejoined, and the drive continued to the quarry in Carnmoney Hill (Fig. 13, p. 144). Here is a great mass of basalt, showing a distinctly columnar structure, and the Director gave reasons for believing that this represents one of the volcanic necks or vents through which the lava was erupted, which now forms the uppermost Basaltic Sheets. The basalt her contains small cavities filled with a glassy material, which has been described under the name of "Hullite," but it is probably Tachylite. The party next drove to Macedon, the residence of Mr. James Thompson, who most hospitably provided afternoon tea; after which, and a ramble round the pretty gardens, the members grouped themselves in front of the house, and an excellent photograph was taken by Mr. Welch. The return was then made to Belfast by the shore road.

On *Tuesday*, 30*th July*, an early start was made by the 7.30 train from the County Down Station to Newcastle. After breakfast at Lawrence's Rooms the party, reinforced by a strong contingent of the Belfast Naturalists' Field Club, drove to Trassey Bridge, and thence proceeded on foot under the guidance of Mr. Praeger, who was acting as assistant-director, up a mountain valley on the north side of the Mourne Mountains, to the Hare's Gap. From this point a very fine view was obtained of this remarkable group of mountains. Slieve Donard, Slieve Commedagh, Slieve Lamagan, Slieve Bingian, and other fine peaks were conspicuous, while northwards the Antrim Basalt plateau, Lough Neagh, and the nearer granite range between Castlewellan and Newry were seen. The Director explained that these mountains consist of a great mass of granite which has burst through Ordovician rocks, and is of uncertain age; but it is, at any rate, newer than the Castlewellan granite, and older than the latest basaltic eruption. He thought it very probable that it was contemporaneous with the Rhyolites of Tardree in county Antrim, and therefore in age between the Upper and the Lower Basaltic Sheets of that county (p. 144), and with this opinion Mr. Praeger agreed (p. 152).

The Diamond rocks (p. 150) were then visited, and in the cavities of the granite many fine specimens of crystals of smoky quartz, mica, and felspar were obtained, and not a few crystals of white topaz and pale blue beryl rewarded the diligent searchers. The walk was continued to the "Castles" of Commedagh (p. 150, and Fig., p. 151,), where the granite, owing to the well developed cross-jointing, has weathered into great detached masses, which look exactly like masonry on a large scale, and are particularly impressive when seen from below. Slieve Commedagh (2,512 feet) was then ascended, and a still more extensive view obtained than that from the Hare's Gap. It included Carlingford Lough, Lambay Island, Howth Head, the Wicklow Sugar Loaf, and the

Isle of Man. The descent was then made to Newcastle, the junction of the granite with the Ordovician rocks in the valley of the Glen River being noted on the way, and after tea at Lawrence's Rooms the party returned to Belfast by the 6.40 train.

On *Wednesday, 31st July*, the members left Belfast, with their luggage, by the 9.5 train from the Northern Counties Station to Larne Harbour. Near Larne there is a good section of Basalt upon Chalk in a large quarry, well seen from the railway. While the luggage was being packed into the *machines* that were to convey the party along the coast road, the Director led the way to the gravels of the old raised beach (p. 146), and several specimens of marine shells and worked flint flakes were soon found. Coming to the shore, the fine section at Waterloo was next examined. Here the Keuper, Rhætic, and Lias (p. 134) occur in succession as flat scars on the foreshore, rising up into a low cliff with a northerly dip. From the Rhætic, *Avicula contorta*, *Pecten*, *Valoniensis*, and *Cardium Rhæticum* were obtained in abundance, and from the Lias, *Ammonites planorbis*, *A. Johnstoni*, *Gryphæa incurva*, *Cardinia*, etc., showing the beds to belong to the lowest zones. The carriages were now ready, and the drive round the coast, northwards, was begun, the stage for the day ending at Cushendall. The road is very picturesque, and, the day being clear, beautiful views were obtained of the Scottish coast, including Stranraer, Ailsa Craig, the Isle of Arran, the Mull of Cantyre, and in the far distance the Islands of Jura and Islay.

The cliffs are generally Chalk with the overlying basalt, with Greensand, Lias, and New Red below, these being mostly concealed by slips (Fig. 2, p. 135). At Ballygally Head is a fine mass of intrusive basalt (p. 145). A halt was made at Glenarm, and while the horses were being changed the party inspected the whiting factory here, for the purposes of which a large amount of chalk is quarried in the immediate vicinity. There is also stacked here, waiting to be shipped, a considerable quantity of pisolitic iron ore, bauxite, bole, and lithomarge from workings in the neighbourhood. These beds of ironstone, bole, bauxite, etc., occur between the Upper and Lower Basaltic Sheets (p. 138), and it is by means of the presence in them of lignite beds with plant remains that the age of the period of volcanic activity can be fixed. This was formerly considered to be Miocene, but the researches of Mr. Starkie Gardner have shown that it is more probable that the plants belong to the Lower Eocene period.*

At Garron Point there are some very big slips of the Chalk over the Lias, and a little farther on, in Red Bay, there are fine sections of Triassic conglomerate (p. 133). Cushendall itself is on the junction of the Old Red Sandstone conglomerate and the earlier Quartz Porphyry, which occurs immediately to the south

* *Quart. Journ. Geol. Soc.* vol. xli. p. 82.

(p 145). This Quartz or Felstone Porphyry, as it is variously called, is traversed on the sea-shore by veins of red jasper, of which some beautiful specimens were obtained. In the neighbourhood of Cushendall is an isolated hill of basalt, called Tieveragh, which is another volcanic neck (p. 144). The headquarters of the Association here were at the Glens of Antrim Hotel, but the members were mostly distributed throughout the village, and some amusement was caused by the fact that most of the houses were owned by families of the same name, which necessitated their being described as 1st, 2nd, or 3rd MacSoandso, according to their distance from the hotel.

On *Thursday*, *1st August*, the drive was continued, the destination being Ballycastle. At Cushendun some remarkable caves in the Old Red Sandstone were visited, the deposit here consisting of a massive conglomerate of quartzite pebbles, many of them of great size, and occasional fragments of porphyry and schistose rocks (p. 131). The whole mass is crushed and sheared in every direction. The carriages were now abandoned, the steepness of the coast road compelling them to go by the longer but easier road farther inland. The members proceeded on foot to Torr Point, passing on the way a quarry near Runabay Head, opened in a dyke of quartz porphyry, with large crystals of red orthoclase. Between Cushendun and Torr Point the country is occupied by a series of metamorphic rocks, schists, etc., of uncertain age, which are very well seen at Torr Point itself, which presents an extraordinary tangle of schists, crystalline limestones, and intrusive epidiorites (pp. 130 and 145). From Torr Point the first view was obtained of Rathlin Island, its white chalk cliffs contrasting finely with the overlying black basalt. At the top of the hill above Torr Point, the carriages were met, and the drive continued to Ballycastle, some sections of boulder clay and river gravels (p. 146) being pointed out by the Director on the way. At Ballycastle the headquarters were at the Antrim Arms Hotel.

On *Friday*, *2nd August*, the party drove to Colliery Bay, so-called from the fact that coal used to be worked here. The coal seams occur in the Lower Carboniferous, which here consists of shales and sandstones (p. 132). The carriages were left here, and the members descended to the beach and proceeded to collect from the highly fossiliferous shales. Many examples of *Productus*, *Spirifer*, *Orthoceras*, *Crinoids*, *Stigmaria*, etc., were found. Walking eastwards a very fine view was obtained of Fair Head, one of the most striking cliffs in Ireland (Fig. 1, p. 131). It is 630 feet high, and the uppermost 250 feet form a solid wall of basalt, composed of very massive vertical columns. The lower part of the cliff is a huge talus of fallen basaltic columns and masses of carboniferous sandstone. The basalt here is intrusive in the Carboniferous as well as the Cretaceous strata (p. 145).

and the Director stated that it is one of the very latest basaltic intrusions in Ireland, or indeed in Britain. The Head was now ascended by a path which gradually degenerated into a sheep-track and finally led up a nearly perpendicular cleft in the face of the basaltic wall, which taxed the climbing powers of the Association to the utmost. All, however, got safely to the top, and here the columns could be seen in section, and they were found to be scored in several places by ice-scratches, the general direction of which was, as the Director pointed out, westwards from the Firth of Clyde. Some perched blocks of granitic rocks were also noticed. A good view was obtained of the coast to the westward, and of Rathlin Island, and Jura in the far distance. The "Grey Man's Path" is a somewhat similar path to that by which the Association came up, and it is marked by a column of basalt which has fallen over the chasm, so as to form a sort of natural bridge. Near here the basalt was remarkable for the fine large crystals of augite which it contained. The walk was continued to Murlough Bay, where the party came down by an easy descent. In this bay the Chalk rests directly on the Trias, with only a bed of pebbles representing the Greensand, and the Lias entirely absent. Below are the Carboniferous Sandstones, and the junction of these with the metamorphic series occurs on the foreshore in the Bay. At Miss Clark's cottage on the beach the members were most hospitably entertained to tea, and much interest was displayed, especially by the ladies, in Miss Clark's spinning-wheel. A return was then made to the top of the cliff, not far from which the carriages were found, and the homeward journey was made to Ballycastle. In the evening the usual speeches were made, and votes of thanks passed, and as Mr. Leighton had announced that this was the last long excursion which he would undertake in the capacity of excursion secretary, his health was enthusiastically drunk, and he was cordially congratulated on the great success of the Irish visit.

On Saturday, 3rd August, an advance party drove direct to the Giant's Causeway, and on to Portrush to catch the mail train there. The remainder drove first to Kinbane Head (Fig. 5, p. 138) which is a low projecting point of chalk, which, along with the overlying Lower and Upper Basaltic Sheets, has been lifted out of its proper place by a later intrusive mass of basalt, the cliffs to the east being similarly penetrated by basaltic dykes. In ascending again to the carriages the Director pointed out the ash-bed, which is composed of *débris* of chalk and basalt, thrown out by the Carrick a Raide volcano (p. 144). The next stoppage was at a small, but very interesting, quarry in the Upper Basaltic Sheet, which showed a beautiful example of columnar structure below, merging almost imperceptibly into the starch like and amorphous form above, due, as the Director explained, to the different rates of cooling of the surface and interior of the mass. The basalt here, as

generally in the Upper Sheet, is extremely compact in texture. The journey was then continued to Carrick a Raide with its famous swinging bridge, over which many of the members, including several ladies, crossed without the slightest hesitation. The rock of Carrick a Raide is a great volcanic vent, and is composed largely of an agglomerate of masses of chalk and basalt (p. 144), and considerable ash-beds spread out in all directions from it. More of these ash-beds were seen in ascending to the carriages at Ballintoy, whence the party drove to the Giant's Causeway, which was duly inspected. It is unnecessary to describe this celebrated locality; it is sufficient to say that it is caused by the lowest bed of the Upper Basaltic Sheet, which in the adjoining cliffs is underlain by the Lower Balsalt, being brought down to the sea level by a sharp dip, and that the Causeway itself is composed of the upper surface of the columns composing this bed, which is seen in the cliff a little further east, where it is known as the "Organ Pipes." The columns composing the Causeway are much smaller and more regular than those at Fair Head, and the "ball and socket" structure is particularly well shown, in connection with which it was noticed that there was no regular system, the upper ends of the columns sometimes presenting a ball and sometimes a socket. The cliffs eastwards, as far as Bengore Head, are very fine, but cannot be compared in grandeur with Fair Head. The distinction between the Upper and Lower Basaltic Sheets is particularly well seen at the "Amphitheatre," a little east of the Causeway (Fig. 6, p. 139), the Upper being columnar, and the Lower not. The beds are separated by the Bole-bed, consisting of red ochreous clay, smaller bands of which occur above and below, marking successive outflows of the lava sheet. Many of the party took up their quarters at the Causeway Hotel, but the remainder continued the drive to Portrush, passing the fine section of basalt on chalk at the "White Rocks," and seeing the intrusive basalt and baked Lias at Portrush itself (p. 134). Several specimens of *Ammonites Johnstoni* were obtained from the Lias here, which, except for the fossils, can hardly be distinguished from the basalt. Here the excursion ended officially, but many stayed on for some days, Mr. Traill kindly accompanying a party along the cliffs near the Causeway on the Sunday afternoon, when the numerous later dykes of basalt were pointed out. Many of the members also visited White Park Bay, near Ballintoy, where most were interested in the kitchen middens and worked flints to be found there (p. 146), though the writer preferred to confine his attentions to the Lias, which crops out every here and there under the Chalk (p. 134), and from it he obtained a fair collection of fossils. Altogether, both in point of arrangements, weather, and geological interest, the long excursion of 1895 must be pronounced a decided success.

For References see p. 146.

EXCURSION TO SEVENOAKS.

SATURDAY, 24TH AUGUST, 1895.

Director: W. J. LEWIS ABBOTT, F.G.S.

(*Report by* THE DIRECTOR.)

UPON alighting at the S. E. Railway Station the party were shown an example of an old river channel running on an anticline, in the deep railway cutting just south of the station. The next halt was at Col. Bevington's, to inspect the sections made by the late Mr. Bevington, J.P., for the purpose of exposing a continuous stratum of carstone, and exhibiting the curious modes of its formation. The collection of flint implements made for the latter gentleman by Mr. B. Harrison, was next inspected with great interest. In another part of the estate a section was visited showing the relation of the Chert beds to the Hythe Beds. Here it was seen that the former, which attain a thickness of between twenty and thirty feet a little farther south, are the result of the silicification and alteration of the Kentish Rag, all stages of alteration being present. The grounds in which this section occurs are left for the preservation of rare and interesting wild plants. Several of the members appeared struck with the luxurious growth of the Canadian Hog weed, which here reaches a height of seven to eight feet. The next section visited was the L. C. & D. Railway cutting, near the bridge close by, which showed one of the curious transverse folds of the underlying beds sometimes found on the counterscarp, indicative of earth movements of a remarkable nature, not suggested by the general strike and dip of the country. By this fold the Hythe Beds are brought up into the Folkestone sands, and except for the presence of coltsfoot, no indication of the beds becoming more clayey is noticeable, and being immediately followed by the Folkestone sands, there is apparently no sign of Sandgate beds present, a condition observable in several parts of the locality. Seale House was next visited, upon the lawn of which tables had been erected to display the numerous relics of pre-historic man, upon the discovery of which the Director has been some time engaged. They belong to, probably, a hitherto un-recognised people, the important feature being that they formed kitchen-middens, not previously found in this county. These people have been traced from Hastings to Sevenoaks, Suffolk, and North-east Lancashire.* They are characterised by one special group of implements, in many ways identical with those found in some of the French caves, and by another of still more highly specialised forms identical with specimens found in India,

* More recently I have found them near Lulworth Cove and Seaford.—W. J. L. A.

Spain, Belgium, and elsewhere. The recovered relics also include a large number of bones and shells, illustrative of the fauna and food of the period, and the state of civilisation attained. The pottery is rude, hand-made, but usually well baked. The implements also include some of bone. At Sevenoaks several settlements of these old people have been found, together with their tumuli. There was also exhibited a large series of stone weapons from the plateau to late neolithic forms, together with examples of modern manufacture, which highly interested the members. The patronage received by the boxes of scrapers, flakes, cores, etc., placed at the disposal of the members, evinced the fact that a much greater interest is now being taken in this subject by geologists, since it has been pushed so much farther back into their province.

One of these old settlements was next visited at the Wildernesse, from which the Director has obtained many thousands of flakes and implements. At this spot also exists one of the most remarkable barrows known. Unfortunately, the excavations had been filled in before the arrival of the Association. It appears that these old fellows first made an extensive hearth of ironstone, upon this they laid the body of the chief, which was covered with flakes and implements to a great thickness. Upon this a wood fire appears to have been lit, which calcined the implements, these going to pieces in the operation, and in many cases fusing at the edges. Before the flints had got cool, white sand was thrown upon the pile, and with it another lot of implements; this deposit was about a foot in thickness, and extended over the whole pile, the implements being less burned as they got nearer its edge. The whole was now covered with some four feet six inches of sand, and rounded off into a mound about ninety feet in diameter.

An interesting section in Lord Hillingdon's quarry, in Seale hollow road, was next seen. It showed Kentish Rag of a lenticular nature, lying in detached flattened ovals, from three to six feet in length, in a bed of hassock. Above this was pointed out a Chert drift upon which the Director has been engaged for some time, and which promises a new feature in the history of the counterscarp. A visit was next made along the Knole Valley to Knole Park, and the history of the old valley, as written by itself, commented upon *en route*. The King Beech, the Old Oak, and Knole Castle, also added features of interest to the excursion. At the close of the journey a vote of thanks was accorded to the Director.

For References see Excursion to the Kentish Plateau, p. 196, *ante*.

ORDINARY MEETING.

FRIDAY, 1ST NOVEMBER, 1895.

GENERAL McMAHON, F.G.S., President, in the Chair.

The following were elected Members of the Association:—
W. H. Chadwick; Charles Ekin; Nicol Brown.

The evening was then devoted to a Conversazione, which was attended by about 250 Members and their friends. The following were the exhibitors and exhibits:—

Miss RAISIN: Specimens of the Flysch from Switzerland, and rock slides of the same.

Prof. BONNEY: Pyromerides from Boulay Bay; Eozoön from Côte St. Pierre.

R. S. HERRIES: A large series of Belemnites from the Yorkshire Jurassics.

J. D. HARDY: Models of Diatoms in clay; Sketches and photographs taken on the Antrim Excursion.

C. DAVIES SHERBORN: Letters from Linnæus, Stephen Hales, John Hunter, and Cuvier.

F. W. RUDLER: Models of diamonds, and a series of cut and polished agates and other specimens.

H. B. WOODWARD: Sandstones and Sands of various ages, from Torridonian to Blown Sand; Photographs of Skye and Raasay, by Miss Jessie Barnard, Mr. A. Evelyn Barnard, and Mr. J. Alison Glover.

The DIRECTOR-GENERAL OF THE GEOLOGICAL SURVEY: *Index Maps* (4 miles to one inch).—Sheet 9 (published 1895); Sheet 13 (published 1895); Sheet 11 (first coloured copy); Sheet 12 (proof of first colour-printed copy). *New Series* (one inch to a mile)—Sheets 329 and 343. *Old Series* (new edition), Sheet 101 S.W.

E. T. NEWTON: The remains of Palæolithic Man, from Galley Hill, Kent, with flint implements from same beds, and large polished celts of modern manufacture from New Guinea; also the shrivelled brains from two skulls of the new Egyptian race, found by Prof. Flinders Petrie.

H. A. ALLEN: A fine example of *Ostrea expansa* from the Portland Oolite, containing cast of the animal.

A. SMITH WOODWARD: Casts of jaws and bones of *Dinichthys*, from the Devonian of Ohio; Rock surface polished by rubbing of Rhinoceros, Cape Colony.

Miss M. Foley : Rock specimens from the Eifel.

A. E. Salter : A series of rocks collected from the Pebble Beds round London.

G. E. Dibley : *Synhelia Sharpeana*, a very rare coral, from the Chalk of Croydon ; a fine jaw of *Portheus*, *Pachyrhizodus Gardneri*, *Ptychodus* tooth, and other Chalk Fossils from Burham and district ; Cestraciont tooth from Warlingham ; *Ostrea* with impressions of sutures of Ammonite from Upper Chalk of Northfleet.

Upfield Green : Rocks and fossils from the Eifel and from Co. Antrim.

D. A. Louis : Rough Sapphires from America ; Silver ores from America.

C. Hansford : Calc spar from Portnaspania, Ireland.

G. Abbott : Jasper implements from the graves of a race recently discovered in Egypt ; Mottled Sandstone, Tunbridge Wells ; Sandstone eroded and decolorised by roots ; Photograph of weathered Tunbridge Wells Rock ; Stereoscopic slides illustrating chemical action in rocks ; views of Oxted Sand Quarries with remarkable iron concretions.

J. W. Crossley : A series of Carboniferous Plants.

H. J. Beadnell : A holed celt from Montgomeryshire.

Dr. F. Corner : A fine series of Flint Implements, chiefly from the East London area ; and a series of Bronze Weapons from the Lower Thames.

F. Chapman : Foraminifera from the Cretaceous beds of New Jersey.

W. F. Gwinnell : Fine series of bones of the Dodo, including complete sacrum ; Photographs taken during the excursion to Antrim.

Dr. W. F. Hume : *Echinocorys* in Mulatto Stone, near Carrickfergus ; Pebble Conglomerate, with *Ostrea vesicularis*, separating Trias from White Chalk, Murlough Bay, Antrim.

J. R. Gregory : A case of gems ; and various gems in the matrix.

R. Elliott : A fine series of flint arrowheads, and other small implements.

J. N. Tervet : Fossils from Burdiehouse ; spine of *Gyracanthus* ; and fine specimen of *Eurynotus*, with drawings of the fossils.

Henry Preston : Photographs taken on Geological Excursions of the Association.

James Love : A series of photographs of the Electric Spark.

J. ALLEN BROWN: Flint Implements illustrative of his Eolithic, Mesolithic, Neolithic, and Palæolithic periods.

A. C. YOUNG: Rock specimens from Antrim and elsewhere.

R. W. HINTON: A series of bones from the Forest Bed.

G. W. LAMPLUGH and W. W. WATTS: Photographs of the Crush Conglomerates of the Isle of Man.

A. M. and Mrs. DAVIES: A series of Rocks and fossils from the Ardennes.

T. LEIGHTON: The Photographic Albums of the Association, showing the geological photographs taken by Members during the Excursions.

RICHARD HALL: Two screens of glass, illustrating a method of decoration by means of sections of Ammonites, Corals, and other natural objects.

ORDINARY MEETING.

FRIDAY, 6TH DECEMBER, 1895.

GENERAL MCMAHON, F.G.S., President, in the Chair.

The following were elected Members of the Association:—W. R. Scammell, H. J. Seymour, Miss Jebb, J. J. Fox, Stanley Robinson, Dr. Alex. Mitchell.

A paper was read by W. H. HUDLESTON, F.R.S., entitled "Notes on Indian Geology, including a visit to Kashmir," and was illustrated by a large series of maps and diagrams, and a collection of rock specimens.

ORDINARY MEETING.

FRIDAY, 3RD JANUARY, 1896.

GENERAL MCMAHON, F.G.S., President, in the Chair.

The following were elected Members of the Association:—F. J. Stephens, Robert Elliott, C. Southall, F. E. Brook-Fox, E. J. Garwood, W. W. Rhodes.

Mr. H. FLECK proposed the names of Mr. JOHN HOPKINSON and Mr. A. E. SALTER as auditors, and of this the meeting approved.

A paper was read by J. E. MARR, F.R.S., entitled "The Lake-basins of Lake-land," which was illustrated by the lantern.

THE NECESSITY FOR COMPETENT GEOLOGICAL SURVEYS OF GOLD MINES.

By NICOL BROWN F.G.S

(*Read June 7th, 1895.*)

INTRODUCTION.

THE late Mr. Jevons wrote a paper in 1859, entitled "Remarks on the Australian Gold Fields," to which far-seeing memoir the writer's attention was drawn by a kindly critic in *The Manchester Guardian*, after he had written and delivered a lecture in Glasgow on "The Profit and Loss of Gold-mining."

Mr. Jevons foreshadows the time "when greater experience is attained in quartz-mining, now so new an employment; when improved machinery is brought into use for the rapid, complete, and cheap extraction of the gold from the quartz matrix; when capital is attracted in great sums to the pursuit; and when the search for new auriferous reefs, becoming more keen, is rewarded," as he says he believes it will be, "by abundant discoveries." He finally draws two conclusions:

I. "That no great and recurring discoveries of alluvial gold are to be expected, so that the yield of alluvial gold must notably yet gradually fall off."

II. "That the supply of gold from its quartz matrix is subject to entirely different laws; that we at present know no limit to the amount procurable with the aid of capital; and that that amount, whatever it may be, will probably remain constant for a long period of time."

At the present time the supply of gold can be drawn, not only from the quartz reefs referred to by Mr. Jevons, but from sedimentary rocks; those from which the largest supplies are at present drawn being the Witwatersrand Conglomerates.

It has, however, taken many years to realise Mr. Jevons' forecasts, as the Gold industry appears to have been one of the slowest to adopt true scientific methods of working, the neglect of which is so detrimental to any practical undertaking.

We shall try to show that Geology in competent hands is the first necessary science for gold-mining; and that no sure foundation is laid for other men of science to base their work on, unless the preliminary work of the geologist is well done. Geologists hold

the key of the earth's storehouses of the royal metal; but until lately, owing to few or no scientific methods being used, they, like other careful men, eschewed having anything to say about gold mines.

We hope to be able to show that Geology may do a useful work in clearing away those strange and baseless (and may be oriental) superstitions about subterranean storehouses of gold, which have followed it through all time and led to extravagance and failure in many ways.

Here is a little fossil, the rare helmet-shaped *Cassidaria*, rolled out of the Red Crag on the banks of the River Deben. To find it would have given many a geologist a delight comparable with that of finding a nugget rolled out of the golden sands of Africa. The possession, however, of golden dust from Africa is of great practical importance to us and all the human race, but until the finding of it receives the consideration of competent geologists, the industry will not attain the stability which is so much required, and which Mr. Jevons, as a political economist, predicted so truthfully it would eventually acquire.

Some practical men would tell us they would rather have the gold than our *Cassidaria*; but, curiously, when these so-called "practical" people seek for the gold in the earth they cannot find it, or find it only by haphazard.

Whether a man goes to seek fossil shells or golden sands, the same qualities are required for success; the same intimate knowledge of Nature and Nature's laws, without which her thrilling secrets cannot be discovered. From the want of this knowledge, the ordinary, uninstructed gold-seeker always defeats the end he has in view. He works hastily and by imperfect methods, and never stops to mark the finger-posts or compass-points which might guide him to the object of his search.

The gold in itself is too much over-estimated; a great portion of mankind, on merely looking at gold, are prepared to bow down and worship it as a kind of fetish, yet it is almost practically useless except for jewels and ornaments; it has to be alloyed with stronger metals before it can be used even as rings or coins. Pure gold is absolutely useless except for standardising purposes. Taken weight for weight, one ton of iron is infinitely more valuable in the workshop than one ton of gold. In the arts, silver, copper, iron, and even the alloy, pewter, can be used to more advantage by the skilled artist than pure gold. As the taste for true art increases, so may we look for the decrease in gold used for ornamental purposes.

In commerce the case is quite different. When one country (call it A) has exported more value in kind to another country (call it B) than A has imported from B, then B must pay A the difference in gold, which has a fixed value. This is called the balance of exchange, and it is for this purpose that it is

principally required. Gold has been described as "the wind of commerce and the tide of trade." It does not create commerce, but keeps it in motion.

The disturbance of the currency which has so long hung as an uncertain factor over the commercial world, appears to have arisen from a want of a sufficient supply of gold. The commercial world wants more gold, so as to meet the expanse of trade and prevent unnatural depressions.

The finding of nuggets by chance, has always set the lazy and the speculative upon the *qui vive*, and it was thus that much of the occupation of gold-seeking was left, until lately, in the hands of non-industrial people. Even now, there are but few bankers in England who would dare to come forward and justify the investing of money in gold-mining; and yet the banker's business is dependent upon a liberal supply of gold.

The finding of gold must no longer be left to chance, but should be the result of well-designed and well-organised efforts; and the basis of that industry which is now being built up, we must reiterate, rests on Geological Surveys made by qualified men. These are now demanded and must be obtained, and the gold-miners can well afford to pay for them, and at a different rate to what hitherto has been done.

Who would think of buying a ship nowadays without a Certificate of Survey by Lloyd's qualified surveyors, and who would think of acceptlng a certificate of survey from such a man as a quartermaster or a stevedore; and yet mines are daily sold in the City of London on the certificates of men who hold positions in the mines such as that held by a quartermaster or stevedore of a ship, and responsible directors of companies even raise such men to the position of captains or managers of mines.

Looking back to the olden times, we find that gold locked in refractory rock-material, such as pyrites, was practically unattainable by the ancients; and the Mosaic expression, "And the gold of that land was good," no doubt meant that the gold of the river-sand was free, attainable gold.

Wherever mining in rocks was carried on by the ancients, it was not pursued to a great depth, and ceased so soon as they came to pyritous ore. The ancients seem to have had some idea about the way in which gold and silver are distributed in nature, in fact clearer ideas than shown by many modern people. In the Book of Job, as Murchison* points out, the natural truth is clearly expressed:

"Surely there is a vein for the silver . . . the earth hath dust of gold."

And he drew attention to the fact that silver-lead veins were

* *Siluria*, 3rd Edn., 1867, page 475.

known to expand downwards in the earth, with great possibilities of future production, whereas gold, though extensively, is more thinly distributed.

The diagram, Fig. 1, shows the relative production of gold and silver for the last fifty years. Taking the lower curve from the date of Jevons' paper, 1859, referred to above, it will be observed that the gold product fell off slightly till quite lately, owing to the failure of supplies from alluvial deposits; and it is now increasing, owing to permanent supplies from rock-crushing, as he predicted.

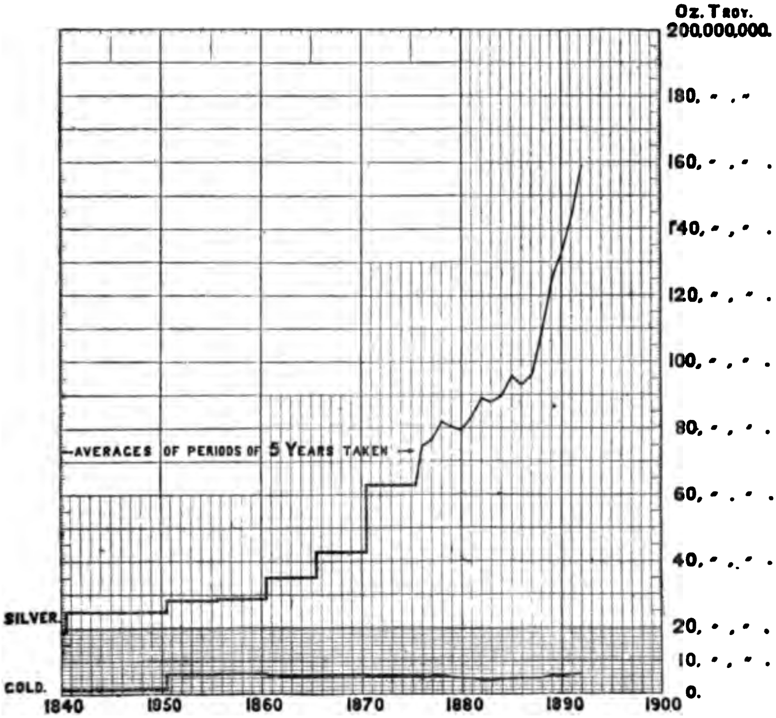

FIG. 1.—TABLE OF THE PRODUCTION OF GOLD AND SILVER FOR THE LAST FIFTY YEARS.

From *The Mineral Industry*, Vol. II. (1893—94).

If the lower curve were divided, showing the gold from alluvial washing and quartz-crushing separately, the alluvial curve would be a decreasing one, and the quartz-crushing a rapidly-ascending one.

The production of silver increased, not only as foreshadowed by Murchison, but also owing to the abnormal stimulus of

production given to it in America by the silver protection laws of that country.

Some of Murchison's views about gold were wrong, for instance, he limited the gold-bearing rocks to the older rock-systems, but he is apparently right on the point before us.

Gold-mining seems to have ceased entirely during the middle ages, as all surface gold in Europe had been previously picked up.

The necessity for gold in the mediæval times appears to have had at least two good effects. It inspired voyagers to seek for new lands, which were supposed to produce gold; and a reference to their old maps and charts shows they are marked in different places with such notes as "Here is Gold." It also inspired the searchings of the Alchemists, which eventually led to the evolution of the Science of Modern Chemistry.

The voyages of Columbus and his successors were prompted by the hope of getting gold; and the discovery of South America was so far successful that the hoards of the Incas were stolen and sent to Spain; but after these hoards were acquired the supply fell off, as only few fresh natural supplies were discovered. The quantity of gold the aborigines had, suggested to the invaders that there were great natural storehouses of it somewhere, and that in time these would be found.

It was thought gold and silver veins might yet be found as large and as rich as those of the inferior metals. Even such a wise man as Sir Walter Raleigh fell into the common snare when he dreamt of his El Dorado.

These absurd ideas, however, existed long before the Spanish Conquest of America.

Geology has now taught us the error of these delusive archaic dreams: and the cold material laws of Nature, as revealed by this science, tell us what may, and what may not, be found.

Geological Surveys.

We shall now endeavour to describe the part a geologist takes, together with others, in contributing to successful gold-mining.

Directors of gold-mining companies have considerable difficulties to encounter in selecting employés who understand the various departments of the work. To the uninitiated, these latter appear complicated; but in reality they are simple to those who take the trouble to spend the time and labour to learn about them.

Directors of gold-mining companies, should, however, themselves learn how to appoint their staff, and to control them by allocating to them their work in such a way as to get the best results.

Instead of this, their aim has been to get what they call an "all-round" man, and thus try to shift the responsibility off their shoulders.

Owing to the confusion existing in the minds of such unskilled persons as to the proper administration of gold mines, the work of the different departments has often become hopelessly mixed. By these persons, the manager is expected to be a geologist, a miner, a mechanic, a chemist, and a business-administrator all rolled into one; but evidently this leads to failure.

Pseudo-geologists, or prospectors without adequate knowledge, have been often employed to survey and report on the properties. Incapable persons also have been entrusted to do the industrial part of the work of mining, milling, and saving the gold.

All this blundering results in heavy loss. So largely has this been the case from the earliest times, that those who have taken the trouble to inquire into the facts, taking good and bad mines alike, have often made the statement that gold costs more to produce than it is worth.

Proper geological surveys, not only of the gold-bearing veins or beds, but of the enclosing rocks, must now take the place of the old prospector's empirical work, in order to prepare the field for the tools of the workers of the mine, who cannot otherwise proceed intelligently with their operations.

The costs of preliminary and concurrent surveys by competent geologists should always be provided for in any gold-mining scheme. The expense of such surveys will be infinitesimal, compared with the money thrown away in times past on many expensive, abortive, El-Dorado-like schemes. Geological knowledge will tell them that there are no regular deposits of nuggets, but only the "mineralised" or metal-bearing beds of rock, which must be worked industrially before they yield up their treasures. When the "alluvial" fields of California and Australia were first discovered, it was only the nuggety gold which was sought for amongst the river-sands, and the value of the hard rocks was little thought of.

If we refer to the annals of these gold-fields, it will be found what a terribly wild speculation this gold-finding proved to be. Stories of the wonderful finds of those days linger in the memory of people still living. Wild, lawless, uncontrolled men flocked to those countries from every part of the world to make their fortunes in a day; and in extravagance and debauchery the majority spent it as fast as they had gained it.

It was slow work, after the subsidence of that gold fever, after the surface nuggets were picked up, for a legitimate gold industry to establish itself; yet such an industry did early spring up in California and Australia. Its development, however, was slow. It early took the form of hydraulic mining, which may be defined

as the art of "extracting gold from gold-bearing detritus, *i.e.*, surface deposits, placers, or washings, by means of [water under] great pressure discharged through pipes against the auriferous material . . . the value of this kind of mining is based on the great facility with which profitable results can be obtained at trifling cost from washing vast areas of ground which contain relatively per cubic yard insignificant amounts of precious metals, but in the aggregate, when expeditiously worked, give large remunerative returns."*

The Geological ages of these deposits are Post-Tertiary and Tertiary.

The early result of the mining and milling of gold-carrying quartz-rock was not encouraging, from lack of special knowledge.

It is only a proper understanding of the way in which gold is locked up within the gravel, or in the sand and clay, the product of the stamps, that leads to a comprehension of the true method of obtaining gold cheaply, at a rate which will offer profit to capitalists. Briefly, it is the proper handling of these hard or intractable substances which renders it possible for anyone to win the gold from their embraces. It is, therefore, necessary to understand in some degree the distribution of gold as seen in nature. Nature must be properly studied before she reveals where her treasures are found. She delights to hide them so that the human race may exert their best talents in finding them.

Gold is found in very small quantities disseminated through the mass of granitic mountains; but so small that to grind up such mountains for their gold would be a costly and unremunerative operation. It is locally distributed in many alluvial deposits, and it is also found in sea-water, in the proportion of about one grain to the ton.

We often hear of rich patches of gold-ore being found in some mines. These should receive careful investigation, as the reports sometimes give rise to much mischief and trouble. Such patches may represent the natural concentration of gold into some place usually called a "pocket"; or it may be a segregation, such as an "eye." It may be very rich, but not extending far in any direction. Thus, if we take a nearly vertical vein (see Fig. 2), and suppose that the part A B has been denuded, and the greatest portion carried into the alluvial sands and gravels, it is possible that, owing to the percolation of surface waters carrying some natural solvent, a small portion of the gold may have been taken into the remaining portion of the lode so far down as C, there locally enriching it. It is such partial enrichments, which, when met with by uninstructed men, are magnified into representative samples of the whole lode.

* "Hydraulic Mining in California," by A. J. Bowie, Junr., *Trans. American Institute of Mining Engineers*, Vol. vi 1877, 1878.

MINING.

The mining operations should be under the control of an educated and experienced mining superintendent. He must be a practical working miner, and should have had experience in mining various ores in different parts of the world. It is a great disadvantage to employ a miner whose prejudices have been developed by long experience of one particular series of rocks, or of the physical structure of one country. Such

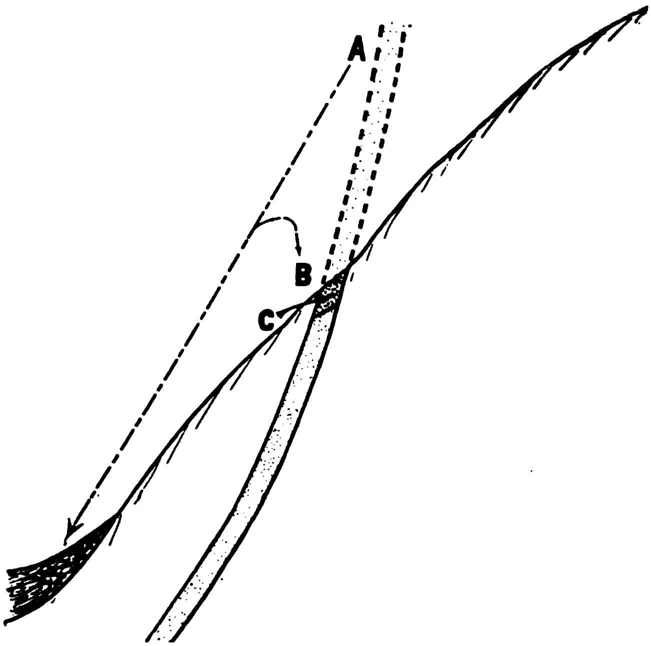

FIG. 2.—DIAGRAM TO ILLUSTRATE HOW A VEIN MAY HAVE BEEN LOCALLY ENRICHED.

a man, however capable otherwise, has no resources when he comes to deal with new geological conditions. Unfortunately, many good mines have been condemned by such men.

The operations often reveal sections of the earth's crust which, when noted by the thoughtful geologist, lead to further following up of the payable deposits; if, however, these sections are left unnoticed and unrecorded, rich opportunities are thrown away.

Mechanical—Crushing the Ore.

Having "torn up the mountains by the roots," as mining was described in the book of Job, and brought the ore "to grass," the next operation is to mechanically crush it, in order to free the gold from the gangue; there is no evidence of this operation having been attempted by the ancients.

The stone-breakers, mechanical hammers, and various crushing appliances of all kinds, do on an artificial scale what earth-movements, the sea, ice, frost, and rivers, have always done with the rocks on a natural scale.

The Californian stamp-mill for crushing the ore is an improvement in detail and adaptability on the old Cornish mill used in tin-stamping, which has been in vogue since the seventeenth century.

By these stamp-mills, which are at present the chief means of crushing, the ore is reduced to a fine state of subdivision, and the battery is flushed with water to act as a carrier of the finely-divided ore or pulp from under the hammers. This pulp is carried over plates coated with mercury, which catches a certain amount of gold, and so saves it in the form of an amalgam of gold and mercury.

The general result of this treatment is great loss in float gold and loss of gold in slimes.

A newer method, which is now attracting much attention, but may not be applicable to all kinds of ores, is to crush the ore dry. This makes the product easier to deal with when a percolation chemical process is used for dissolving the gold out of the ore instead of taking it out by amalgamation with mercury.

At the Witwatersrand the power is obtained from steam; and, as there is a coalfield in the neighbourhood, this is easily and cheaply obtained. Johannesburg owes its rapid rise to being on a coalfield as well as on a goldfield; the combination of the two has caused the success of the place.

We can also obtain power from water, and, with the aid of electricity, transmit the power even for a hundred miles, and, if need be, drive machinery in a mine which may be on the top of a hill. With water power near them, mines have as good a factor for work as if they were near a coalfield. This greatly widens the areas in which gold ores can be worked, and operations formerly impracticable can now be carried on at a profit.

Metallurgical and Chemical Processes.

Although, as observed above, the origin of modern chemistry sprang from the searchings of the alchemists, whose aim was principally to make gold out of some other metal, it is strange that, while the ancient chemist devoted so much attention to

gold, the modern chemist has, until recently, left it severely alone. Even though scientific chemists have now become alive to the importance of their science in its application to gold-extraction processes, the commercial and so-called practical men in charge of mines often do not see its full importance.

However, the "chlorination" process was introduced, and afterwards the "cyanide" process (the most recent of all the chemical processes now in practical use), and considering the short time the latter has been in vogue, it has had an extraordinary influence on the gold industry in South Africa and other places. The process is a simple one.

It was long known that the cyanides had an affinity for metallic gold; but, as they had also an affinity for the baser metals, the extraction of gold from ores by this means was not considered feasible. Mr MacArthur and Dr. Forrest, however, discovered the interesting fact that "cyanide" in certain conditions had a strong selective affinity for gold, and that, by utilising this and employing weak solutions, the economical recovery of gold from ores might be accomplished.

Referring to the stamp battery treatment, it is found that the flocculent clayey tailings consolidate into hard and impervious masses which defy percolation; but if the sand grains had not been separated from the clay, they would have kept open channels for the percolation of the cyanide liquors. It is apparent, therefore, that the process of separating the sand and clay into two varieties of tailings is a mistake, if a percolation process is to follow.

A method of dry-crushing the ore, as indicated above, seems to be the best adapted for this process; and when this shall have been carried out practically, and the dry-crushed ore treated directly with the cyanide, without the use of mercury-covered plates, it is hoped that another stage may be reached in the profitable saving of gold.

There are many other processes competing for the success which the cyanide process has achieved; as yet there are none equal to it. There is, however, no finality in these matters; and the great impetus given to research will doubtless lead to good results.

Examples of Good Geological Surveys.

As an example of the kind of geological work which should precede any attempt at mining, let the reader procure the special geological reports on particular gold-fields—such as Professor William Nicholas' papers, *The Golden Quartz Reefs of Australia* and *The Bendigo Quartz Reefs Strata*, Mr. E. J. Dunn's *Report on the Bendigo Gold-Fields of Australia*, or Mr. A. R. Sawyer's *Report on the Mashonaland Gold-Fields*, or Professor Clayton's *Report on the Montana Mine*—and it will be seen how variously Nature has worked in each case, how carefully and cunningly she has hidden

away her golden treasures in the folds of her garment, and how these treasures can only be found out by a painstaking study of the geology or physical structure of the earth. Such reports, had they existed only a few years ago, "would have saved enormous waste of time, labour, and lives." They are evidence that a better state of things is growing up in the gold industries, while the handsome dividends paid by some of the great gold-mining companies show the profits which may be derived from a careful working of the business, based upon intelligent and scientific treatment.

Mr. Harry Page Woodward's *Mining Handbook to the Colony of Western Australia* is another great advance in the dissemination of valuable scientific knowledge; and it has this great merit, that it was published well in advance of the general rush to these gold-fields. It has been written by a very competent man, and is prepared expressly for prospectors and strangers to the Colony who are interested in mining. It will thus supply many a hard-working man with a scientific "vade mecum" which will surely help him to do his work with less toil and more certain purpose than ever could have been dreamt of in the days of former "gold rushes." Instead of the ignorant cackle of the mining canteen, where prospectors have usually picked up their scraps of information, they have here the well-digested hints of an able geologist; and it argues well for the future of Western Australia that the van of the prospectors has been led by Mr. Harry Page Woodward.

Amongst the recent literature on the subjects which have been considered in this paper, mention may be made of "Curtis on Gold-quartz Reduction," a paper read before the Institution of Civil Engineers in 1892; *Louis on Gold-Milling* (1893), in which the costs of numerous mines throughout the world are detailed in tabular form; Abraham's *New Era in the Witwatersrand Gold-Fields* (1894), in which the average product of the ore of the district is given as 14 dwts.; this, however, is only the product, and not the contents of the ore. It is better in practice to deal with the gold contents of the ore, and not the gold extracted from the ore, as, unless this is done, the probable losses always going on in the process are never discovered.

Mr. Abraham's book is, however, very valuable to all nterested in the Witwatersrand mines, as it gives the dip of the reefs and methods for approximately calculating the life of a mine in that district.

Mr. Hamilton Smith, jun., published in *The Times* in January, 1893, a report on the Witwatersrand Gold-Fields. That report led to the Prussian Government sending out a mining commissioner, Herr Bergrath Schmeisser, who came to similar conclusions as those of Mr. Hamilton Smith as to the great extent of the Witwatersrand deposits.

Cost of the Production of Gold.

While yet the old style of gold-seeking prevailed and men were prepared to risk their all in hazardous adventures, unguided by sufficient geological knowledge, hoping to find a great subterranean store-house of gold, the cost was never counted or even thought of. They dreamt that the bare possibility of wealth which could be taken out of the earth by shovelfuls rendered the necessity of counting the cost needless.

The new style is quite different, and the most practical way of now counting the cost is by the number of pennyweights of gold. For instance, it is now usual to say that an ore carrying ten pennyweights of gold to the ton will cost seven pennyweights in its extraction. The cost varies, of course, with the difficulties of mining and extraction.

As ten pennyweights of pure gold are worth £2 2s. 4d. it follows that, as seven pennyweights are worth £1 9s. 7d., which is the assessed cost per ton of extraction, a profit is left of 12s. 9d. per ton of the ore handled.

These low costs are possible for mining, milling, and cyanidizing the ore.

Conclusion.

Nearly the whole of the iron and copper obtained in ancient times has perished by the corroding action of the atmosphere; here and there an old battle-axe or a Greek helmet may have resisted the destroying influence of time; but, taken as a whole, it may safely be said that the work anciently spent upon obtaining these metals has all disappeared.

If the condition of gold is compared with other metals, it is seen to be quite different. Gold is a durable metal, and the gold now in use is mingled with the product of very many past centuries. In much of it are represented the rich surface nuggets found in primæval times, probably obtained by forced or slave labour, by the Phœnicians, the Romans, and the Carthaginians. Some part of the actual gold of Solomon's temple, of the crowns and jewels of emperors and kings, whether Roman, Saxon, or Spanish, or the ancient hoarded stores of India, may be still handled in the sovereigns passing over the counters of any of our banks.

The total gold produced in the world for the thirty-seven years ending 1892 is by the best authorities estimated to be 217,000,000 ounces; and, if it is reckoned as the product of ore carrying on an average one ounce to the ton, it will represent the crushing from 217,000,000 tons of ore.

The space occupied by one ton of ore is 15 cubic feet; and, to obtain the above number of ounces, 3,255,000,000 cubic feet of rock would require to be removed and ground up. To give some idea of the work which has been done (and

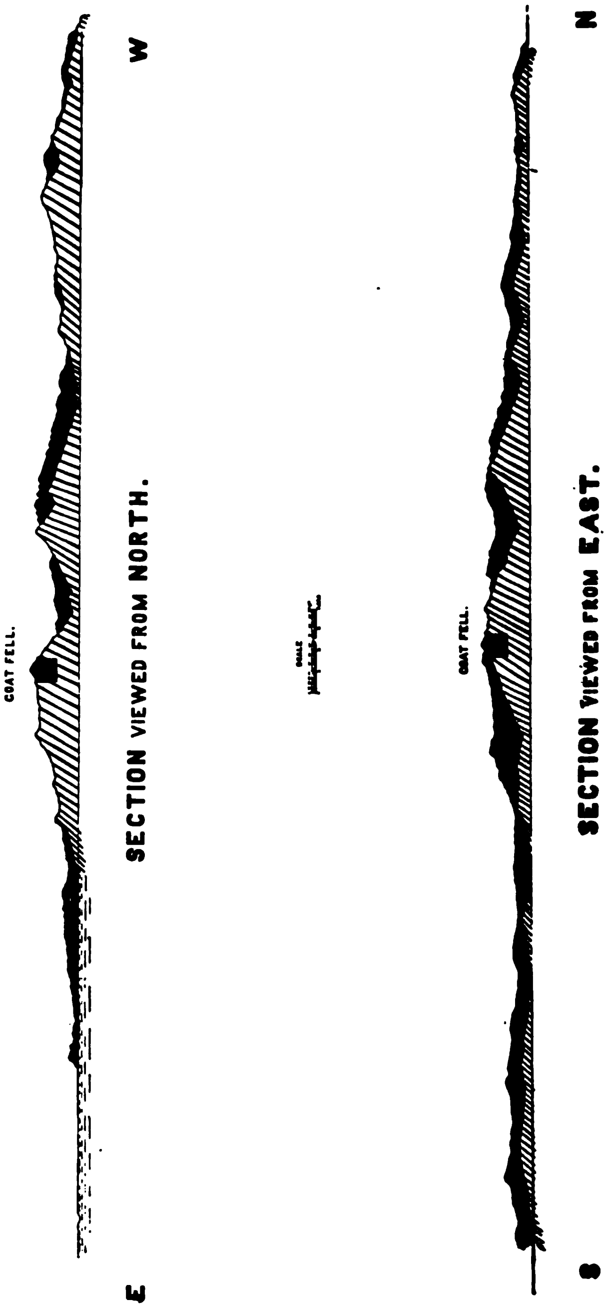

FIG. 3.—DIAGRAM SHOWING BULK OF ORE TAKEN TO PRODUCE THE WORLD'S GOLD IN 37 YEARS.

which has really been very small) the small cube in the centre of Fig. 3 illustrates the amount of rock which would be removed out of such a hill as Goatfell, in Arran (which, of course, is non-auriferous) to obtain the results in gold during the said thirty-seven years. This is giving the calculation the credit of all gold obtained in hydraulizing as well as by quartz-crushing.

Or take another illustration, the number of tons of coal produced in the world during *one* year, is over 500,000,000, or more than double the tons of quartz required to make the world's production of gold during the last thirty-seven years.

It has been the aim of this paper to show that the chance of men finding much gold in massive nuggets and becoming suddenly rich has for ever vanished. To continue the necessary supply of gold to carry on the ever-extending commerce of the world a vast industry of the first importance, aided by many sciences, is needed to gather out the infinitely small scattered portions of gold as they exist in nature.

The product in gold of the industry which has recently sprung up will afford relief to the straightened currency of the world; and, as it can now be procured with the industrial and scientific certainty predicted by Jevons, the result to the world will, in the near future, be very great.

The governor and directors of the Bank of England may hold the key of the bank's gold, but the geologists hold the golden key of knowledge to the earth's storehouses of the kingly metal; and although it cannot be counted up like gold in the bank, they, and they only, can be relied on to survey the new gold-fields which may yet be found. If this be done, the still potent survivals of mediæval or oriental superstitions, ever ready to delude again and again a too gullible public, will definitely die out.

Men cannot nowadays keep slaves to work their gold mines as of old; but, always provided that they work upon the basis of proper geological surveys, the mining, mechanical, and electrical engineers, and the metallurgical chemists, with all the far-reaching fingers of their various sciences, can gather out the countless small particles of gold from the rock-matrices and pile them into the bank storehouses.

Industry must be set off against industry; our future gold, got by well-directed industry, will represent the result of men's honest toil.

Gold so obtained will reach a steady value, as compared with a speculative value; it will neither become greatly "appreciated" nor "depreciated," as the supply will constantly keep pace with the requirements of commerce; it will help to keep the countless mills of many different industries in continuous motion, without intermittent periods of fluctuating trade, and thus bring benefits to many people in all parts of the earth.

NOTES ON INDIAN GEOLOGY,

INCLUDING A VISIT TO KASHMIR.

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With an Appendix by LIEUT.-GENL. C. A. McMAHON, V.P.G.S.

[*Read 6th December*, 1895.]

INTRODUCTION.

ANYONE wishing, like myself, to make a few remarks on Indian Geology, as the outcome of a recent tour through part of the country, could not find a more fitting occasion than the present, when the Chair of the Association is occupied by a distinguished Indian geologist, who, though not a professional, has contributed valuable original work to the literature of the Indian Survey. Indeed, it is mainly because an Indian geologist occupies this chair that I venture to put before you this evening a few remarks, based upon my recent tour; not, indeed, that I could hope to contribute anything original of real importance, but simply to bring to your notice some facts in the geological history of that country to which my attention has been especially drawn in one way or another.

Outside Europe, and some portions of North America, there is perhaps no country in the world which has been more systematically surveyed, in a geological sense, than India, and the condensed result of all this work may be seen in the map which accompanies the second edition of Medlicott and Blanford's *Manual*, which has been edited and brought up to date by Mr. R. D. Oldham. The geological features of this map, on a reduced scale, are reproduced in Plate VII. As a matter of curiosity, and by the way of comparison, it may be interesting to exhibit a geological map of India, compiled by Greenough and published by Petermann, of Charing Cross, in 1854. The Geological features of this map would, no doubt, be severely criticised by a modern Indian surveyor, nor is the topography in all cases accurate.* The publication of Greenough's map may be said to mark the close of the first era in the geological investigation of India, an era mainly of non-professional enterprise, but one which was rendered famous by palæontological discoveries of Crawford on the lower Irrawaddy, of Falconer and Cautley in the Siwalik Hills and of Fulljames and others in the Gulf of Cambay. These discoveries relate exclusively to Upper Tertiary fossils, and will be dealt with more especially when we come to consider that group. Meanwhile it is interesting to note that two years after the publica-

* He makes the Jhelum, for instance, a portion of the Pünch River.

tion of Greenough's map, namely in 1856, the *Memoirs of the Geological Survey of India* first made their appearance, whilst the *Palæontologia Indica* was at the same time commenced by Stoliczka; the *Records of the Geological Survey of India*, did not appear until 1870. Thus, during the last forty years, the work of the Indian Geological Survey has been progressing, under the able management of men like Oldham, Medlicott, Blanford, Valentine Ball, Wynne, Lydekker, R. D. Oldham, and a host of others, amongst whom we note with pleasure the name of C. L. Griesbach, formerly known to many members of our Association, who is now at the head of affairs in this department at Calcutta.

Before venturing to narrate any of my own experiences, I will, with your permission, sir, give a brief outline of the physical history and geological divisions of India, taking as my principal guide the latest edition of the *Manual*, where references to special papers in the *Memoirs* and the *Records* may be found. Nor should I forget to mention in this connection the work of the late Valentine Ball, whose recent death at a comparatively early age, is so much to be regretted. If we wish, on the other hand, to obtain an insight into the views and operations of the earlier geologists, these may be found in the *Palæontological Memoirs of Hugh Falconer*, edited by Charles Murchison, and published in 1868. The first volume of this work bears the title "*Fauna antiqua Sivalensis*," and it carries us back to the period of the thirties, when Falconer and Cautley were making their memorable discoveries in the Siwalik Hills.

Many of these discoveries were announced at the time in the publications of the Asiatic Society of Bengal, of the Geological Society of London, and of other learned institutions. I merely mention these things to remind you that the study of Indian Geology is by no means a thing of yesterday, and that there is a large and interesting literature bearing on the subject.

The most superficial glance at the Survey Map to which I have referred will serve to show that, physically, India consists of three distinct regions, namely, Peninsular India, the Indo-Gangetic plain, and Extra-Peninsular India. This important geognostic feature cannot be realised on an ordinary map, but on a geological map we at once perceive that the great alluvial flat which curves round Peninsular India, from the mouths of the Indus to the mouths of the Ganges, consists of one formation, which has filled up a sort of gulf or strait between the Arabian Sea and the Bay of Bengal. It is just possible that at one time this may really have been a marine strait, in which case Peninsular India must have been an island. However, the deposits of this great flat give evidence, it is said, for the most part, of fluviatile action, and it is certain that the strait, if ever it existed, has long since been filled up by the spoils of the

Himalayas from the North, and to a lesser degree by the deposits of the Central Indian rivers. Although practically a plain, this great flat has a slight east and west slope towards the Ganges and Indus respectively. Roughly speaking, the watershed, if such a term can be applied to what seems a dead flat, runs from the last spurs of the Arávalli mountain system near Delhi, almost along the line of the Delhi-Kalka Railway, to Umballa, which latter place is about 1,000 feet above sea-level. The Jumna flows parallel to this railway for many miles, and evidently marks debatable ground, since General MacMahon, in his presidential address, states that this river at one time belonged to the Indus system. At present the river Markanda, which immediately succeeds the Jumna on the west, is lost in the sands of the Indian desert, though apparently with the intention of reaching the Indus, if it could. The head waters of the Markanda are famous for great finds of Siwalik fossils.

But to return to the tripartite division of India; for the present I have said enough about the Indo Gangetic plain and its monotonous alluvium. It is time to consider the more interesting subject of the Peninsular and Extra-Peninsular areas, which exhibit a more or less complete sequence of the great geological systems. But these systems differ so much in each area that it has been found necessary to describe them in duplicate. The geology of Peninsular India, judged by European standards, is the most abnormal, and marine fossiliferous strata are very scarce, and occupy but a small extent of surface. The geology of Extra-Peninsular India, omitting the region east of the Ganges delta, of which I do not profess to speak, may be said to consist of an immense horse-shoe of mountains, which curve round the plains of the Upper Punjáb. Notwithstanding the complications produced in such a region by the existence of an alpine facies in many of the deposits, these conform, on the whole, to the European standard better than do the formations of Peninsular India.

PART I.—EXPLANATION OF THE MAP AND SUMMARY OF INDIAN GEOLOGY.

Section A.—**Peninsular India.**—An immense proportion of this area is occupied by crystalline rocks, such as granites, gneisses, and basalts, which, with the exception of some intertrappean beds in the basalts, are, of course, wholly unfossiliferous. Hitherto the Transition rocks have proved equally so, and, strange to say, the great sedimentary series known as Vindhyan has never yielded any fossils, although its unaltered and almost horizontal beds seem to be just the sort of place where one would expect to find them. Consequently palæontology has given but

little aid in the classification of these rocks, and it is only when we come to deal with the Gondwána system that anything approaching a chronology based on fossils can be attempted. But as regards the relative age of the lower rock groups there can be but little doubt, and the crystalline system at the base may be fairly regarded as Archæan.

Crystalline (*Gneiss*, *Granite*, *etc.*).—It is possible that many systems may be comprised under this heading, but on the whole the Surveyors divide the series into an older and a newer gneiss. The older gneiss is largely developed in the northern part of Central India, in the district know as Bundelkhand, and may almost be looked upon as the *omphalos* of the entire Peninsula. It is distinguished by its massive structure and obscurely developed foliation, whilst accessory minerals are rare. Quartz reefs occur in this older gneiss, but they are non-auriferous. The district round Jhansi, which we visited on our return journey, may be taken as typical. A specimen of the rock is described in the Appendix.* In the field the Jhansi rock behaves very much like granite, as may be seen in the Jhansi cantonment, where an undulating area is full of protuberances like the tors of Dartmoor on a small scale, whilst the rock on which the fort is built offers a larger example of the tendency to form protuberances.

The newer gneiss, which is well developed south of the Vindhyan basin, presents greater variety in its mineral composition. Thus we read of limestone, dolomite, massive corundum, and magnetite occurring in conjunction with quartzite, quartz-schist, hornblende rock, and mica-schist.

We cannot doubt that large areas, both in the older and newer gneiss, but especially in the former, may be regarded as granite, and it is probable that much of the area coloured as "Crystalline" in the map would come within the definition of granite.

Transition Systems.—This is admittedly a generalised grouping, capable of being broken up into more than one subdivision. The several areas are only approximately similar, and their connection more or less conjectural. The beds of this system in N.W. Mysore are interesting as carrying the paying gold reefs, and many of them are rich in hematitic iron. The iron industry, however, for the present, may be regarded as almost extinct; as much, says *The Manual*, in consequence of the reckless destruction of forests as owing to the competition of imported iron.

In Rajputana and the neighbouring districts the Transition beds attain to great importance in connection with the Arávalli system of upheaval, the effects of which may be traced as far as Delhi. This mountain system is one of the oldest in India, and I shall have occasion to refer to it again in connection with the subject of Mount Abu.

* No. 1, p. 262.

*Vindhyan.**—The Vindhyan Beds represent the upper portion of a great sedimentary series, vaguely referred to the older Palæozoic, but which is quite as likely to be pre-Cambrian, possibly of the age of the Torridon sandstone. The almost horizontal Vindhyans are supposed to bear the same relation to the upturned Transition formations of the Arávalli mountain system that the modern deposits of the Indo-Gangetic Plain bear to the Himalayas: that is to say, the horizontal series in each case is contemporaneous with the upheaval of the mountain range with which it is associated, and of whose *débris* it is, to a great extent, composed.

Although the Vindhyans are described as consisting mainly of fine-grained sandstones, there are some shales and limestones, and towards the base conglomerates. It is not proposed to deal with these lower sedimentaries, so as to emphasise distinctions between Vindhyan and Cuddapah; but there are certain points of general interest to which reference may be made. We have already seen that they are wholly unfossiliferous, although their aggregate outcrop is the third largest in Peninsular India. But there is one feature of considerable interest in connection with this system, viz., that the beds are the chief, if not the only, home of the diamond in India. For not only are the workings in the solid rock entirely in beds of this system, but even the alluvial diggings for that gem can, in nearly all cases, be traced to them.

Where is Golconda? That is a question I never could get anybody in India to answer, whilst the name is not mentioned either in *The Manual* or in Ball's work.† At present there are three principal diamond districts in India. In the Madras Presidency there are certain beds in the Vindhyan (Cuddapah) system which are regularly worked for diamonds; these beds consist mainly of sandstones, but the diamonds are said to occur in the more clayey and pebbly layers. However, the most historical diamond district in India is probably that of the Mahánadi valley, though here the diggings are alluvial. The Mahánadi, according to Ball, is the river "Adamas" of Ptolemy, and the neighbourhood of Sambalpur may be roughly taken as the centre of a diamond district, which furnished the Mogul emperors with some of their most celebrated stones. The third diamond district is near Panna in Bundelkhand, where according to *The Manual*, "the original home of the diamond is in the lower part of the Upper Vindhyan series, though the possibilty of its derivation from Lower Vindhyan beds has been indicated."

* In the index to the map, attached to *The Manual*, Upper (Vindhyan) and Lower (Cuddapah) = Older Palæozoic.

† Since this paper was read a friend has called attention to the following: "Golconda, a fortified and ruinous city of Hindostan, Nizam's dominions . . . on a hill 3 miles west of Hyderabad; lat. 17° 15′ N., long. 78° 32′ E. It has been noted as a depôt for diamonds, which are, however, only brought hither from the plains at the base of the Neela Hulla morntains, on the banks of the Krishna and Penaar rivers, no mines existing in the vicinity. . . ." *A. K. Johnston's Dictionary for Geography*, 1845.

It seems to have been the opinion of Ball and other writers that the diamond really did originate in the Vindhyan rocks, although no attempt to account for its genesis in connection with these rocks has been made. On the other hand, Mr. R. D. Oldham considers that the diamonds are derivative, that is to say, they occur, like any other pebble or stone, in its matrix. In the absence of any theory to account for the genesis of the diamond in connection with the Vindhyan rocks we must regard this as the most reasonable supposition, although it is indeed a remarkable circumstance that a particular horizon should be the sole repository of the gem in a country of such great extent. The primal origin of the diamond in India seems to be as obscure as ever.

Gondwána (*Upper and Lower*).—Between all the beds previously described and the system now under consideration there must be a great gap in time, since the Gondwánas are completely unconformable to all the underlying beds. The Gondwána beds, in their present distribution, occupy a number of separate basins, and those in the north-east angle of Peninsular India are the best known and of great economic importance. The fossils of this system, of freshwater and terrestrial origin, afford the earliest signs of life which have hitherto been made known in Peninsular India, although the age of the beds only dates from Carboniferous to Trias, or, if we include the Upper Gondwána, to Jurassic.

The sandstones and shales of this great freshwater formation include Labyrinthodonts, Fishes, Insects, Crustacea, Mollusca, etc.; whilst the Plant remains are abundant, and afford evidence of several successive floras. These are regarded as ranging from Upper Palæozoic to Middle Mesozoic, and the Lower Gondwánas approximately correspond to the Carbon-Trias of extra-Peninsular India. There is considerable lithological variety in the several districts. The Rajmahal group, for instance, consists of a succession of basaltic lava flows with inter-stratification of shale and sandstone; and it is noteworthy that the most characteristic sandstones throughout the series contain abundance of undecomposed pink felspar. The celebrated Talchir boulder-bed occurs towards the base of the formation. The indications of glaciation, which it is thought to present, are also noted in the Carboniferous beds of the Salt Range, and elsewhere in the extra-Peninsular area.

The Gondwána Beds contain practically all the workable coal in that portion of India which is included within the accompanying map. Of 2,750,000 tons raised in 1894 the Bengal coalfields contributed 2,000,000 tons, and the Nizam's territory accounted for 250,000. The Tertiary coal of the Punjáb, from which so much was at one time expected, only yielded 66,000 tons. There can be little doubt that the development of the great Gondwána basin in Chotia Nagpore, is only a question of

time, and with increased railway facilities, such as have been lately proposed, a large output may be expected. At present Bombay and Western India are mainly supplied by seaborne coal from abroad, an unfortunate circumstance for the railway companies in those parts. This is the great advantage which the East Indian Railway Company possesses over all other lines, that its wants are entirely supplied by two collieries in Bengal, which are worked in connection with that line.

Cretaceous.—No marine beds of Jurassic age being recorded in Peninsular India we pass on to the Cretaceous. There is a very interesting strip in the neighbourhood of Trichinopoly, which has yielded, probably, the oldest marine fossils in the Peninsula. Three horizons are indicated—viz., Cenomanian, Turonian, and Senonian. It is interesting to note that there are extensive coral reefs towards the base of the system. Another feature of importance is the ever-increasing number of Gasteropods, including many genera of Siphonostomes, which are especially well-developed in the very highest beds. These have been described in Stoliczka's classical memoir, which forms the introduction to the *Palæontologia Indica.*

Deccan Trap.—This formation occupies the second largest area, but is not so thickly bedded as the Vindhyans and Gondwánas. The period of its eruption is held to occupy the interval between Middle Cretaceous and Middle Eocene. There are intertrappean fossiliferous beds, such as might result from the covering up of marshes and lakelets. Their facies (not marine) is thought to be more inclined to Cretaceous than Eocene. The Great Indian Peninsula Railway runs through the Deccan Trap for 500 miles from west to east. Throughout a large portion of the area the horizontal terrace formation prevails; the beds in the Deccan being flat and rather thin. The terrace formation is noticeable also in the Western Ghâts, but between this elevated platform and the Indian Ocean, there is a strong westward dip in the beds, which increase in thickness, those nearest Bombay being highest in the series.

Within certain limits the lithological character of the rock is tolerably uniform. In some places blocks of scoria may be seen weathering out, just as they do in old volcanic cones, this phase being very noticeable in the Ghâts and around Poonah, also in Bombay Island and Salsette. In texture the rock varies from an anamesite to highly vesicular beds containing various amygdaloids. Zeolites in such beds are especially numerous, the crystals of stilbite and apophyllite being celebrated for their size and beauty.

The origin of such an immense mass of basaltic rock has been the subject of much discussion. It was probably due to subaerial eruptions, since most of the intertrappean fossils are of freshwater species. It is stated that no vents have been dis

covered; but dykes are tolerably abundant throughout the coast region, and older rocks are seen to be pierced in Cutch and Kathiawar. By some this extensive extravasation is supposed to have been connected in some way with the disappearance of the hypothetical Lemuria.

The Tertiary Beds may be considered along with those of the extra-Peninsular area.

Section B.—**Extra-Peninsular India.**—*Crystalline* (*Gneiss, Granite, etc.*). Following the same order we take the crystalline rocks first. These, of course, constitute large areas in the Himalayas, but there they have been so much twisted about and injected with granite that their true nature is not easy of interpretation. General McMahon, in his presidential address (1895), described the character and position of many of these rocks, which usually occupy the most elevated position in the Himalayan ranges. As regards the term "Gneissic," the editor of the second edition of *The Manual* admits the difficulty of distinguishing between granitoid gneiss and gneissose granite. He is also alive to the difficulties which arise from apparent sedimentation, difficulties which the earlier surveyors probably did not sufficiently appreciate.

Transition Systems.—These include the Vaikrita system of Griesbach—micaceous schists, talcose-rocks, phyllites and gneiss—occupying the cores of highly compressed synclinal folds in Hundes and Spiti, not indicated by colour on the map.

Cambro-Silurian.—This must be held to include a wide scope of beds. In the Salt Range, for instance, it will be found to include both pre-Cambrian and Cambrian beds; whilst under the general term of "Attock Slates," is a great series, coloured pale-blue on the map, corresponding in the main to Lydekker's Panjal system in Kashmir. The older Palæozoic fossils are barely in evidence throughout the Himalayan region, and we must turn to the Salt Range for more conclusive proofs.

The Salt Range, though only 150 miles in length from east to west, contains a sort of epitome of nearly all the marine fossiliferous horizons of extra-Peninsular India. In a country where all fossils are scarce (the Siwalik beds excepted), this is a point of great importance. In the eastern portion of the Salt Range the sequence is not so full, and we miss especially the really abundant Carboniferous fauna of the central and western portions.

Taking the Salt Range as a whole, we obtain the following horizons below the Carboniferous:

(1) The Purple Sandstone group of pre-Cambrian age. This series contains the Salt deposits. The base is not seen, so that no Transition or Crystalline rocks are exposed. It is thought to be of the same age as the Vindhyan, both being equally

unfossiliferous, though there is said to be considerable lithological similarity.

(2) The Lower Cambrian. The fossils are contained in a dark shaly series, which underlies a rock locally known as the Magnesian Sandstone. Subsequent to the publication of Mr. Wynne's memoir, Dr. Warth has extended our knowledge of this fauna, and he claims to recognise the following sub-divisions in descending order: *Olenus*-fauna, *Paradoxides*-fauna, *Olenellus*-fauna, *Neobolus*-fauna. This last assumes considerable importance as the oldest recognised fauna in India, or possibly in the world. With one exception it consists of Brachiopoda, having shells of a horny calcareous nature. The genera differ from those previously known, excepting *Lingula*. There are two species of *Neobolus*, one of which is rather plentiful.

(3) The Magnesian Sandstone and Salt-pseudomorph zone, which overlie the shales, containing the Lower Cambrian fauna, may in part represent the Upper Cambrian and Silurian. The Salt-pseudomorph zone was originally regarded as Trias by Wynne.

Carboniferous to Trias.—Mr. Wynne's original divisions of the Carboniferous have undergone some modification, and the following grouping is now adopted, viz.:

Productus-limestone,
Speckled Sandstone.

There is much that is interesting in connection with the "Speckled Sandstone," especially as regards the boulder-bed, and the striated and even facetted rock fragments, which are held to be indications of glaciation, as in the Talchirs of Peninsular India. To the boulder-bed of the "Speckled Sandstone" the underlying Magnesian Sandstone has largely contributed, and certain crystalline rocks are identified with masses which occur *in situ* 750 miles to the southwards. Some would identify this boulder-bed with the "conglomeratic slate" of Blaini in the Simla district, and with other slaty conglomerates of the Himalayan region. It is interesting to note that the fauna of the "Speckled Sandstone" has Australian rather than European affinities.

The overlying *Productus*-limestone, which for India seems to have yielded a very respectable number of fossils, possesses a fauna whose general facies is Upper Carboniferous to Permian, nor is there a single species identical with those in the bed towards the base of the "Speckled Sandstone." The connection now is rather with Europe and other parts of Asia, whilst there is a singular mixture of typical palæozoic and mesozoic forms.

In the Himalayas a fair number of marine Carboniferous fossils have been found in the mountain mass which lies immediately north of Kashmir city. The general facies differs considerably from that of the Salt Range, but if the fauna is rather older than that of the *Productus* limestone, the circumstance may

be thus explained. Associated with the Carboniferous beds, and possibly with older beds, in Kashmir, is an important series of igneous rocks, held to be contemporaneous lavas. Reference will be made to these in Part II.

In the Simla district there are no marine fossils, and the beds are spoken of as "Carbonaceous," yet without coal. The famous Blaini Conglomerate occurs about half-way between Kalka and Simla—a "conglomeratic slate" in association with carbonaceous shales. A large series of quartzites succeeds, and there seems to be a considerable amount of indefinite rock which is held to belong to this system. In the Dalhousie district, lying between Simla and Kashmir, General McMahon has described some carbonaceous beds with associated basic volcanic rocks, underlain by a conglomeratic slate, all held to be of Carboniferous age.

The upper portions of the area, mapped as "Carboniferous to Trias," are, no doubt, mainly of Triassic age, and in the Salt Range are represented by the Ceratite-beds. Lamellibranchs, such as *Megalodon* and *Dicerocardium*, are held to be characteristic, along with *Spirifer* and some curious Ammonites. The Trias in the central Himalayas is characterised by a great thickness of limestone, and there is an abundant Cephalopod fauna in the lowest beds. The equivalents of these beds, so largely developed in Spiti, may be found at either end of the Vale of Kashmir, and in the Hazara (Abbotabad).

Jurassic.—Marine beds of this age are well developed in Cutch and the adjacent islands, whilst there are numerous isolated exposures in Western Rajputana. In Cutch the base is constituted by the Lower Oolites, succeeded by Oxfordo-Kimeridgian, Portlandian, and Tithonian. Limestones are not particularly abundant in the series, which also seems poor in corals. The Ammonites are the principal indicators of European relationships, and such well-known species as *Am. macrocephalus* and *Am. perarmatus* are recognised. Marine Jurassic beds are also found in the western portion of the Salt Range, whose lithology and palæontology are said to incline towards the types in Cutch; in both areas the Kellaways fauna seems well represented. The Spiti shales of the Himalayas are stated by Dr. Waagen to contain a very different fauna. Some of the Ammonites from this quarter, it is well-known, have been invested with a sacred rather than a scientific character.

Cretaceous.—Beds of this age are well developed in Afghanistan, beyond my sphere of observation. There is also a development near Abbotabad, to which attention will be directed in Part II. Of course, the never-failing Salt Range presents us with its special series. The authors of *The Manual* observe that it is not possible to separate the Cretaceous and Eocene on any but palæontological grounds.

Eocene Volcanic of Himalayas.—Associated with the Lower Tertiaries in the valley of the Upper Indus are some very basic eruptives which are regarded in the main as contemporaneous.

Lower Tertiary.—According to the grouping adopted by the Indian Survey, the Lower Tertiaries comprise the Eocene Nummulitics and their equivalents, together with beds of Miocene age, such as the Nahan, or Murree beds. The arrangement is not altogether satisfactory as regards Northern India. In fact, there would seem to be no analogy whatever between the marine fossiliferous Nummulitics of Eocene age and the unfossiliferous sandstones, etc., referred to the Miocene period, thus grouped together.

The Lower Tertiaries are strikingly exhibited by the long strip of beds in the valley of the Upper Indus near Leh. A portion of these beds consists of a coarse blue limestone containing numerous discs, which are supposed to represent Nummulites, and two species of Nummulites have actually been recorded, also indications of other shells. Stoliczka took these beds for palæozoic rocks, a conclusion not to be wondered at when we bear in mind the rarity of fossils and the vicissitudes which the rocks themselves have undergone. As proof of the changes of level since early Tertiary times, these Eocene beds rise to a height of 21,000 feet in the Stok Peak opposite the town of Leh.

On the opposite or south-west side of the central crystalline axis of the Himalayas there is a long strip of Lower Tertiaries, narrow in the Simla district, but widening out towards the north-west in the neighbourhood of Murree. The Lower Tertiaries are also well developed in the Salt Range and in the Rawal Pindi plateau. The Simla area having been the first studied, the names of the several series are derived from that district. The Sabáthu group at the base is obviously of marine origin and Nummulitic age as shown by the numerous fossils it contains. The two upper groups, which go to make up the Lower Tertiary of the Survey, are really of Miocene age. They possess a variety of Indian names, but are best known in the far north-west as the Murree beds; they are probably on nearly the same horizon as the "Nahan" of the Mount Tilla section. These beds are composed almost entirely of mechanical sediments and contain no fossils other than plant remains, and are held to be of freshwater and to some extent of subaerial origin.

There can be no doubt that a great physical change had taken place between the period of deposition of the marine Nummulitics and of these unfossiliferous mechanical deposits. That change was no less than the upraising of the Himalayan mountain system, which, *as it now exists*, must be regarded as mainly, if not wholly, post-Nummulitic. Doubtless, as our President has so well pointed out, the Himalayan area had a previous history, but to this I need not at present refer.

Upper Tertiary (*Siwalik*).—These are by far the most interesting and fossiliferous of all the Indian formations, and they are distributed in strips over an immense area. Falconer pointed out that the Siwalik beds may be regarded as forming three points of a triangle, viz., the foot of the Himalayas on the north, the Gulf of Cambay on the west, and the Irawaddi valley in the far east. As I indicated in the Introduction these far off points have been rendered famous by great finds of fossils. Omitting Lower Burmah and Perim Island, let us confine ourselves to the sub-Himalayan region.

The Siwalik Hills, as developed between the Ganges and the Sutlej, have a length of about 270 miles. The structure and composition of these hills was described by Cautley in *The Transactions of the Geological Society of London* as long ago as 1836. We learn also of their structure from Falconer in the *Fauna antiqua Sivalensis*, and more recently from *The Manual of Indian Geology*. The annexed diagram (Fig. 1) is a sort of compound of sections by Falconer and R. D. Oldham.

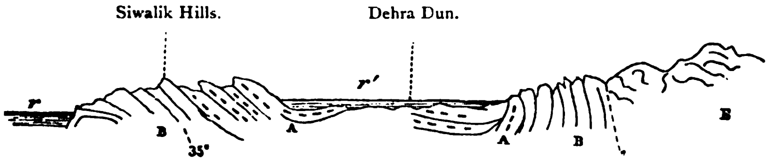


FIG. 1.—HIMALAYAN FOOT-HILLS.—*After Falconer and R. D. Oldham.*

r. Recent alluvium of the Indo-Gangetic Plain.
r'. Recent deposits of the Dehra Dun.
A. Upper Siwalik conglomerate.
B. Middle Siwalik Sandstones.
E. Pre-Nummulitic rocks.

One point of interest in this Section arises from the circumstance that, owing to the interposition of a longitudinal valley or "Dun," the Siwalik Hills stand out as an independent range. There is every variety of junction section between the Himalayas and the plain, but as a rule the beds first encountered dip inwards—in this case at an angle of about 35 degrees. Moreover, it will be observed that in this section the whole of the Lower Tertiaries are faulted out, as seems to be the case everywhere between the Jumna and the Ganges.

Lithologically the Lower and Middle Siwaliks are characterised by a great thickness of fine grained grey micaceous pepper-and-salt sandstone, interbedded with clay bands near its lower portion. The Upper Siwaliks consist largely of soft, earthy clays (very like the alluvium of the plains) mixed with coarse conglomerates, formed of rounded pebbles and boulders of crystalline and metamorphic rocks derived from the Himalayan ranges.

The subject of the Siwalik fauna is far too large to admit of more than a passing allusion. The mollusca are scarce and belong to freshwater and terrestrial forms, identical, or nearly so, with living species. But, of course, the greatest interest attaches to the vertebrate and especially the mammalian fauna. For an account of these I must refer to the *Fauna antiqua Sivalensis*, and to Mr. Lydekker's recent publications in the *Palæontologia Indica*. Falconer and Cautley often collected their fossils at the foot of the cliffs, thus reaping the harvest of centuries of waste. It is true they had been anticipated to a certain extent, for as far back as the middle of the fourteenth century (1360 A D.) bones of elephants, and of what were supposed to be men, had been discovered in digging through a big hill, and were thus brought to the notice of the Emperor at Delhi. We are not told whether the Great Mogul possessed a museum, like the Maharajahs of our own days. In the present century the work was done in a very systematic manner, and we read that the collection of fossils which Captain Cautley presented to the British Museum amounted to 200 chests, each averaging about a hundredweight of contents, the whole amounting to ten tons.

Falconer pointed out the analogy between the existing vertebrate fauna of India, as far as it goes, and the extinct Siwalik fauna ; of which the existing fauna is held to be a mere remnant. Besides the mammalia. there are abundant remains of crocodiles and chelonians, and some birds, including species of Grallæ of immense size. All these creatures lived on the land and in the rivers of a region fairly analogous to the Indo-Gangetic plain. Indeed, the Siwalik beds may be regarded as representing the Pliocene portion of that depression, which after having been lowered to immense depths (these beds are 10,000 feet thick) became involved in the Himalayan uplift. It seems probable that Falconer regarded this assemblage of animals as covering a longer period than the Pliocene, and if we were to be guided by purely palæontological evidence, much might be said for this view of the case. But a careful study of the local evidence, and relations of the Siwaliks to preceding and succeeding beds has brought about the conclusion that they are mainly of Pliocene age.

PART 2.—BOMBAY TO SRINAGAR.

Having briefly sketched some of the leading features of Indian Geology in its dual aspect, I will now narrate some of my own impressions, though still continuing to borrow largely from the constituted authorities. It must, however, be admitted that such impressions are merely superficial, and truly, if such a geologist as Murchison was called to account for practising his profession in gigs, how much more difficult is it to read the features of a country from a railway carriage or a tonga.

Our party, that is Professor Blake, my wife and myself, landed at Bombay on the morning of the 27th of January last. The city is built on a tongue of low-lying land with basaltic supports, which are especially obvious in the Colába Peninsula (the southern extremity of Bombay Island), and still more so on Malabar Hill, a much higher promontory, where are situated the Government House and the villas of the Bombay fashionables, both native and European. In the clear air of a winter's day, as seen across the rippling waters of Bombay Harbour, the picturesque outline of the basaltic hills in the direction of the Ghåts adds much to the beauty of the landscape. It will readily be understood that, having much to do in making arrangements for our up-country tour, we did not pay any special attention to geological matters, though I regret not having made the attempt to inspect the celebrated inter-trappean bed on Malabar Hill, which has yielded some interesting fossils. I console myself with the reflection that the site is now most probably built over, and consequently no longer accessible. With regard to collections, it must be remembered that Bombay is a city of merchants, and the geological surveyors reside mainly at Calcutta. I never heard of any Government museum here which contained any fossils, and the same must be reported of every town visited by us throughout the journey. Hence I never had an opportunity for examining any collection of fossils, though there are a few in the museum of the Bombay Natural History Society.

This museum is kept in excellent order by the secretary, Mr. Phipson, to whose interesting demonstrations we were greatly indebted. His live snakes, including cobras, pythons, etc., are a remarkable feature of the collection. Birds, birds' nests and eggs, shells, and some few fossils were also passed over in rapid review, and we thus obtained, in something less than an hour, a considerable insight into the natural history of the district. Mr. Phipson had lately procured a portion of the jaw of a rhinoceros from the Siwalik beds of the Gulf of Cambay. This is a well-known locality, whence Captain Fuljames, as before stated, obtained a large series of mammalia now in the museum of the Geological Society, which were specially described by Falconer in *The Quarterly Journal* forty years ago. The best fossils were found in a conglomerate bed on Perim Island, at the entrance of the gulf. This bed lies below high-water level, and, as in all other Indian localities for fossil bones, yielded to the first collectors a rich harvest. Owing to the erection of a lighthouse on Perim Island the principal fossil bed may no longer be blasted, and collectors will have to confine their attention to an extension of the horizon on the mainland. The fauna comprises ten species of mammals, and is thought to be a little older than that of the Siwalik Hills, though the absence of *Elephas* and its subgenera may have been the result of local accidents.

As regards the basalt of Bombay most of the exposures exhibit a dark aphanitic rock, and this, as far as I remember, is the character of the basalt at the Caves of Elephanta, where the pillars and sculptures are hewn out of the living rock, which is close grained and exceedingly tough.

After leaving Bombay, on arriving at Surat we already found ourselves on the alluvium surrounding the Gulf of Cambay. Consequently there is no geological observation to record until we reach Baroda. This town is also on the alluvial plain, though within sight of a hill called Pawargha, which may possibly be the southern termination of the Arávalli mountain system. The new museum at Baroda is a really fine building, though, perhaps, somewhat deficient in light: here we left our friend, Professor Blake, duly installed as the organising curator.

From Baroda the railway runs through a rich alluvial country, past Ahmedabad, half-way between the Gulf of Cambay and the Run of Cutch, and on the confines of Guzerat and Rajputana it enters the rocky district connected with the Arávalli Range. I have already explained that this mountain system consists to a large extent of the rocks described as "Transition," whose north and south strike and high angle of dip may be traced even as far as Delhi. It is the most ancient mountain system in India, and what we now see are the mere stumps of a chain, whose denudation largely contributed the material for the Vindhyan rocks—themselves, as I shall presently show, of pre-Cambrian age.

We quitted the train at the Abu Road Station, where the line passes through a long north and south upland hollow at the junction of the "Transition" and "Crystalline" systems. This hollow, or valley, is, perhaps, a dozen miles across, it is bounded on the east by the peaked and irregular ridge of "Transition" rocks, which constitute the Arávalli proper, and on the west by the granitic range of Mount Abu, which attains an elevation of about 4,000 feet.

The ascent of this mountain, which contains an important sanitary station towards the top, is one of the chief features of a tour in Western India. Gentlemen ride up on horseback, and ladies are drawn in rickshaws by coolies. The distance is sixteen and a-half miles, of which the first four miles are on the almost level surface of the upland hollow. The range of Mount Abu rises very steeply from this level, and, as far as I could judge, consists entirely of granite. No doubt this is bedded to a certain extent, and in one place I noticed some schistose rock, but almost all parts of the mountain to which I had access consist of a very felspathic granite showing little or no foliation.* The scenery is peculiar; there are some curious peaks and knobs of rock; those knobs which are close to the plain having a re-

* No. 2 in Appendix, p. 262.

markable *moutonnée* appearance. The knobs, like the tors of Dartmoor, are no doubt due to the superior hardness of certain portions of the rock—a feature so very characteristic of granite. Altogether the scenery and physical structure of Mount Abu and its surroundings are exceedingly interesting, and seem to invite further investigation, more especially as to the relation of the Crystalline to the Transition series. Moreover, I may mention that the character of the vegetation attracts the attention of travellers coming from the alluvial plains. Here it was that we saw the only approach to anything that could be called a forest throughout the whole journey between Bombay and Peshawur. The deficiency of timber, other than ornamental, in India has been remarked by many people besides ourselves. Nor is this deficiency confined to those parts of Western India visited by us, for Valentine Ball, the Geological Surveyor, mentions that railway sleepers had to be imported in large quantities owing to the deficiency of native timber. Amongst the causes of this deficiency are frequent jungle fires, intermittent cultivation, and the ravages of stock, more especially of goats.

We must now pass over a considerable tract of country, and I draw your attention to Jeypore, the interesting capital of one of the principal Rajputana states. This city exists in duplicate: the modern town is on the alluvium, whilst the ancient and more picturesque town is partly built on the slopes of Transition rock of the Arávalli system, which occupy a large extent of country hereabouts, though nowhere attaining to any great elevation. Throughout this district are a number of rugged, ridge-like hills, which, as far as my own observation goes, consist of quartz schist and rocks of a similar character. But at some little distance from Jeypore in the same Transition system are marble quarries, which I regret that we were not able to visit. Much of the marble employed in building the Taj at Agra is said to have been obtained from here. Before quitting Jeypore I should at least refer to the museum, which is really a magnificent building, and contains many curiosities, though I could find no fossils.

The next place of interest is Agra, where we at last reached the Gangetic plain. Here the Jumna flows between steep banks of alluvium, past the walls of the Taj, which if not built of marble are certainly veneered with it. This marble is perfectly white, and appears to be as good as the best Italian in quality. The buildings in the Fort at Agra are likewise of remarkable interest, and we perceive the same kind of material and architecture at Delhi and Lahore. The stone used in these buildings consists largely of a peculiar purplish-red sandstone, which is obtained from beds belonging to the Vindhyan system situated at Futtehpore Sikri, some eighteen miles to the west of Agra.

At Delhi the alluvial plain through which the Jumna flows is about 700 feet above sea level. But immediately on the west of

the city rises the celebrated ridge, which is in reality the northern termination of the Arávalli system, consisting of the same sort of quartz-schist, quartzite, etc., tilted at high angles with a northerly strike. Truly, there is no more interesting spot in all India, replete as it is with memories of the Mutiny. For it was the existence of this ridge which enabled a small band of heroic soldiers to conduct the siege of Delhi to a successful issue. The besiegers made this ridge their fortress, and thus, fairly secured against attacks, were enabled to establish batteries, from which the walls were breached and the city ultimately stormed. If the capture of Delhi saved India to the British, as is by no means improbable, the proximity of this old quartzite ridge to the capital of the Mogul Emperors may be truly said to have determined the fate of an Empire.

A railway journey of a hundred and twenty miles enabled us to cross the Indo-Gangetic plain in a northerly direction, and we found ourselves at Umballa, which is within view of the Himalayas, as we saw a snowy mountain about 12,000 feet in height, probably the Chor peak. Continuing our journey northwards, night fell before Kalka was reached, so that we passed through the Siwalik Hills without seeing them; and in the morning found ourselves in the sub-Himalayan region, 2,400 feet above sea-level.

The distance from this place to Simla by road is fifty-seven miles, or about double what it is in a straight line. The route crosses the strike of the beds, and in this way goes right against the grain of the country, the beds being for the most part tilted at very high angles. This route also may be said to follow the water parting between the Ganges and the Indus. If it is difficult to geologise in a gig, matters are not much mended by being in a tonga; consequently I can only give very superficial impressions. It was obvious to me that we passed through two totally different rock systems, and I afterwards learned that the first rock-group is the classical ground of the Lower Tertiaries, whence the names Sabáthu, Kasauli, etc., are derived. Near Kalka almost vertical beds of hard siliceous rock are interwoven with shaly beds, and about six miles from that town these rotten shaly beds, or mud-stones, have caused a landslip, which is continually giving trouble. We shall see presently, when dealing with the Murree beds, that this tendency to form landslips is rather a characteristic feature of the Lower and Middle Tertiaries. The true Nummulitic horizon, or Sabáthu beds, I cannot say that I recognised. These are said to consist principally of greenish-grey and red gypseous shales with merely lenticular bands of impure limestone. Consequently, there are no fine limestone escarpments, such as one would see in the Alps in an analogous position, and the scenery is on the whole disappointing. Indeed, our verdict on the Lower Tertiaries of the Himalayas may be

summed up as follows: a confused mass of precipitous slopes, but no distinguished peak and no commanding precipices.

Beyond Solon, which is a sort of half-way house, there is a complete change in the character of the rocks, and hereabouts we must have passed close to the celebrated Blaini-conglomerate. These are the Carbonaceous beds of the Simla area, utterly unfossiliferous and with a very indefinite lithology. At Simla itself quartzites and beds with some mica are chiefly in evidence. The position of Simla on a rocky and well-wooded amphitheatre, whose crest lies 7,000 feet above sea level, is magnificent in the extreme, and the view of the central snowy range, from the Mall on a clear winter's evening, leaves nothing to be desired.

Having thus had a peep at the Himalayas in winter, we returned to the plains of India as fast as the tonga could carry us, and after a detention of some days at Umballa set out by rail for the Punjáb. There are only two points I would notice in our journey to Lahore: first, that the Sutlej is almost deprived of its water at this time of the year by the immense drainage canal which taps it higher up; and secondly, that the alluvium of the plains through which we were travelling was obviously of a more sandy nature than that farther to the south. The Museum at Lahore is pretty well patronised by the public, but the natural history department as usual is rather weak. I saw no fossils, but there is a specimen of coal from the lowest Eocene strata at Chitteedand (?) in the Salt Range. The seam is stated to be 24 inches thick and the "present excavation" 700 tons per annum, delivered at Khewra Station at 9 Rs. per ton: this specimen was presented by Dr. Warth. There is also a sample of coal found in the Chamba Hills presented by Mr. B. Powell.

Our next point was Jhelum, a small town and civil station on the river of that name (the ancient Hydaspes), where at length the great plain of India with its monotonous alluvium may be said to terminate. The situation is remarkable and if the day is clear may to a certain extent be realised, though in hazy weather nothing particular can be seen. But this is really the gateway leading to the plateau of the Northern Punjàb, and is situated in the wide gap between the easternmost spurs of the Salt Range on the left, and on the right the slopes of the north-west Himalayas culminating in the snowy Panjal. The axis of the Salt Range is almost at right angles to that of its gigantic neighbour, so that its eastern spurs point directly at the Himalayan slopes, but never reach them. The stratigraphical facts in connection with this circumstance are important, since they show that a failure of the elevatory forces in the intervening space was the initial cause of this wide flat, through which the waters of the modern Jhelum and its predecessors have passed.

It is now time to say a few words about the Salt Range itself, which I have already indicated as the most important in all India

in a palæontological sense. Indeed I don't know what the Indian Surveyors would have done without the Salt Range, which epitomises the geological history of the country in a way that no other mountain range does in any part of the world. And yet, in this region of gigantic ranges its dimensions are very moderate, the usual elevations being about 3,000 feet, though in its western bulge as much as 5,000 feet is attained. The length of the chain from west to east is about 150 miles, with a marked escarpment towards the south, and more gradual slopes in most cases towards the north Punjàb plateau; this plateau is sometimes known as the "Potwar," and I shall subsequently designate it as the Rawal Pindi plateau. You perceive that the Salt Range is very much doubled up in two places, being compressed, as it were, between the Sulimán range, west of the Indus, and the north-west Himalayas. Consequently the strike is sometimes twisted and the dip transposed, but, on the whole, there does not seem to be much inversion, so that the beds are usually in their proper places, and often lying at moderate angles. This peculiarity lends itself to the formation of mural cliffs and cañons, which one does not often see in the outer Himalayas.

Much more might be said as to the orography of the Salt Range, but to us, as geologists, its composition demands attention. I have already mentioned that the oldest fauna in India, perhaps in he world, has been yielded by the Salt Range, but there is a still lower bed, viz., the Purple Sandstone, in which the salt is found. This constitutes the base of the system. It would occupy too much time if I were to detail the entire composition of the Salt Range, and must therefore limit myself to the beds below the Carboniferous, which are more especially seen towards the eastern end. The reader is referred to Part I. for particulars.

Nowhere are the Crystallines reached, but the Purple Sandstone group is clearly pre-Cambrian, and Dr. Waagen is disposed to correlate it with the Vindhyan of Peninsular India, the presence of so much rock-salt and gypsum being regarded as a mere local accident, whilst the lithology of the sandstones is said to correspond closely. The total thickness of the pure rock-salt at the Khewra Mines is about 250 feet, occurring in five beds; the impure salt, gypsum, marl, and sandstone bringing the whole group up to about 1,500 feet. Respecting the age of these beds there can be no longer any dispute, but as to the origin of the rock-salt there are at least three theories afloat. The most natural explanation is that of evaporation, as was undoubtedly the case with the salt of Triassic age in our own country; but, whatever the cause, we find the usual accompaniments of rock-salt, viz., gypsum, marl, and dolomite. Hence some people advocate a theory of replacement, so that the salt is not regarded as contemporaneous with the beds in which it occurs, and may be of

any age; whilst others regard the salt as the result of some form of volcanic action.

In the Magnesian Sandstone group we have seen that the dark shaly beds at the base contain the lowest Cambrian fauna, and it is thought by some that the *Neobolus*-beds pass slowly, by intercalations of sandstone, into the Magnesian Sandstone. As regards the so-called "Salt-pseudomorph zone," this is now attached to the Magnesian Sandstone, and the whole can scarcely be regarded as newer than Cambrian. The total thickness of the Magnesian Sandstone group, including the Lower Cambrian shales, may be about 1,500 feet.

I have been thus particular in detailing the oldest beds of the Salt Range (1) because of the economic importance of the salt; (2) because of the interest attaching to the *Neobolus*-beds; and (3) because of the grand escarpments produced by the Magnesian Sandstone; which, together with the *Productus*-limestone and the Nummulitic limestone, contributes so abundantly to the formation of those mural precipices for which the Salt Range is famous.

It would be satisfactory, if I had time, to give details of the higher beds, but this cannot be done, and I must now proceed to a particular description. For this purpose I have selected Mount Tilla, in the hope that the study of this mountain may give us some idea of the orography and composition of the Salt Range. Before dying out to the eastward, as previously described, the Salt Range gives off three fingers, the Bakrála Ridge on the north, the Tilla Ridge in the centre, and the Kharian Ridge, which lies mainly south of the Jhelum.

We approached Mount Tilla by way of the curious old town of Rotás, for which Dina, rather than Jhelum is the most convenient railway station. The Tilla Ridge is stated by Wynne to have a total length of twenty-six miles, and its eastern termination just reaches as far as the grand trunk road, which lies a little to the east of the railway. It may be said to consist of two very distinct parts, viz.: an eastern portion where the uplift has not thrust the lower beds through the Siwaliks, which here form the principal rock of the low-lying districts. This portion is about twelve miles in length, and is mainly distinguished from the rest of the Siwaliks by the higher pitch of the beds; these are nearly vertical, and being more compressed produce a low secondary ridge, which is obvious enough as one rides over the country. Suddenly, in the neighbourhood of Mongli, about eight miles west of Rotás, the uplift becomes very pronounced, and the lowest beds of the Salt Range are thrust up through the upturned Siwaliks in the manner indicated in the accompanying diagram, which is extracted from Mr. Wynne's Memoir. The effect is to produce a mountain 3,242 feet at its highest point, which, as seen endways from the low position of the railway at

Dina, is exceedingly picturesque and effective, and continually increases in interest as one rides along the low crest of the secondary ridge towards the actual base of the mountain. All along this low ridge the upturned edges of the Siwalik conglomerates are very accessible and considerable finds of mammalian remains have been made by Dr. Aitchison, F.R.S., the well-known botanist, to whom I am greatly indebted for information and assistance rendered.

It would be difficult to select a spot which exhibits so much variety as Mount Tilla. Towards the south, beyond the Jhelum, are the monotonous plains of the Punjàb, here about 800 feet above sea level; this kind of prospect may be followed, in the mind's eye, to Kurrachee on one side, and to Calcutta on the other. Westwards is the prolongation of the Salt Range, and

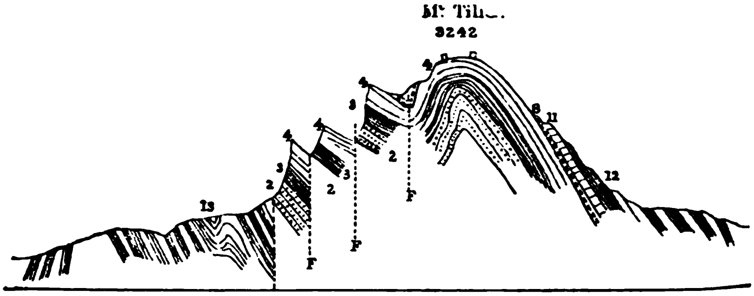


FIG. 2.—EASTERN SPURS OF THE SALT RANGE.—*After Wynne.**

2. Purple Sandstone (Upper).
3. Lower Cambrian—*Neobolus*-beds, etc.
4. Magnesian Sandstone.
8. Salt Pseudomorph-zone.
11. Nummulitic Limestone.
12. Nahan (Murree beds, Miocene).
13. Lower Siwalik.

* *Mem. Geol. Surv. India*, vol. xiv (1878), p. 125.

northwards is the curious country known as the "Potwar," or, as I prefer to call it, the Rawal Pindi plateau. This plateau shows the widest spread of Siwalik beds anywhere to be found; but here the Siwaliks instead of forming a range of hills, as in the typical district, constitute an upland region of moderate elevation, with the beds tilted at high angles and often lying in well marked synclinals and anticlinals. In the far east, across the broad vale of the Jhelum, are seen the slopes of the north-west Himalayas culminating in the heights of the Pir Panjal, which attain elevations of about 15,000 feet.

We must now consider the structure and composition of Mount Tilla itself, by the aid of Mr. Wynne's excellent diagrammatic section (reproduced in Fig. 2). The numbers refer to his original sub-divisions of the Salt Range, but these sub-divisions have been somewhat modified of late. For instance, the "Salt-

pseudomorph zone," which he doubtfully referred to the Trias, is now classed as part of the Magnesian Sandstone group, and may therefore be regarded as of Cambrian age. Of the missing numbers, 5, 6, and 7 represent the Carbon-Trias so splendidly developed in the western portion of the Salt Range; 9 and 10 represent the Jurassic and Cretaceous, also absent here. It follows, therefore, that the Nummulitic Limestone (11), here exceptionally thin, finds itself in some way or other in juxtaposition with the "Salt-pseudomorph zone" of Cambrian age. No. 12 represents the Miocene Tertiaries, or equivalents of the Murree beds, which gradually pass further north into the Pliocene Tertiaries or Siwaliks (13). These latter are seen to encompass the mountain on either side, forming the country of the plain.

Of course, this must not be accepted as typical of the structure of the Salt Range generally, where the roll over is less pronounced and the beds more regular. We must remember that the Tilla ridge is only one of three fingers given off by the Salt Range as it dies away before quite reaching the roots of the Himalayas. The remarkable series of step faults, whilst it adds greatly to the interest of the scenery, is also exceptional. Nowhere in India have I seen such mural precipices as are caused by this repetition of the Magnesian Sandstone resting on the Lower Cambrian shales. As one stands on the low platform of almost vertical Siwalik beds, and looks up at the apparently horizontal tiers of cliffs overhead, rising one above the other into clear blue sky, it is difficult to realise that, owing to results of this great upthrow, the oldest beds of the earth's crust that have a history look down upon the youngest, with whom they are thus strangely brought into juxtaposition.

The throw of this fault, then, you would say, must be tremendous; yet this is apparently not the case, and, if Mr. Wynne's calculation as to the thickness of the beds composing Mount Tilla be correct, the dislocation is not so great as one might suppose. It seems probable that in one part or other of the Salt Range there is a complete sequence of all the marine fossiliferous horizons—Palæozoic, Mesozoic, and Eocene—and that the aggregate volume of these is exceedingly moderate. But towards the close of the Eocene period this style of deposition underwent a complete change, so that in Middle Tertiary times enormous sandy, earthy, and conglomeratic accumulations, now no longer marine, became the order of the day. Whilst the entire palæontological column, up to and including the Nummulitic Limestone, does not exceed a few thousand feet, the aggregate thickness of the Middle and Upper Tertiaries is probably not less than 15,000 feet, thus indicating that an important physical revolution had occurred within the area since the close of the Nummulitic period.

As a mere piece of scenery Mount Tilla is admirable, and an

excursion to the summit will well repay both the tourist and the geologist. One may ride up all the way, and ladies are carried in dhoolies. On leaving the rest-house at Mongli, the path lies along the upturned edges of the Siwaliks, which exhibit in one place a magnificent conglomerate 150 feet in breadth. The path now turns the eastern flank of the mountain, and, amid a mass of talus and loose blocks, gradually and imperceptibly attains the older rocks. Following this path in a direction parallel to the axis of the mountain one ultimately arrives at the summit, which is found to consist of the Magnesian Sandstone, which is so often repeated in the southern cliffs. I submit a specimen from the summit, and also a specimen of the overlying "Salt-pseudomorph" rock, a red flaggy marl which occurs in a sort of synclinal hollow a few hundred feet below the summit. Above this comes a notable pisolite, of which I also submit a specimen. Its true position in the series is unknown to me, and I have sometimes suspected it to be an outlying fragment of Nummulitic Limestone.*

We must now leave the Salt Range and travel over the "Potwar" plateau in the direction of Rawal Pindi. Seldom has one such an excellent opportunity for studying the geological features of a district as is afforded by this railway. As far as the Sohàn Valley nothing is to be seen except Siwalik beds, earthy in some places; but the usual pepper-and-salt sandy beds predominate, along with some conglomerates—a constant succession of synclinals and anticlinals, with here and there a rib of harder sandstone standing out like a trap-dyke. These ribs of sandstone are often charged with fragments of bone, as may be seen at Riwat, which is situated on the summit of the plateau south of the Sohàn River. One thing I learnt on this journey, viz.: how alluvium is formed, and how such a quantity of gravel comes to be mixed with it. Although on the map Siwalik beds only are indicated in this area, the solid geology is often largely masked by a high level alluvium; in railway cuttings and natural drainage sections one sees every stage of decay in the upturned edges of the Siwaliks, until they are literally buried in their own ruins, and earthy alluvium mixed with gravel, in more or less horizontal beds, covers the face of the country (Fig. 3).

In the gorge of the Sohàn, about five miles south of Rawal

* If the prospect from the salient cliff is one that tries the nerves, it also delights the senses. On looking over the edge of the precipice our party surprised a pair of the Salt Range wild sheep, which trotted off very elegantly. No cliffs that we saw in India can vie with these as an appropriate nesting-place for vultures, which are fairly numerous, though occasionally disturbed, I fear, by the crack of a rifle. There can be no doubt that the Salt Range generally, owing to the mural character of its cliffs, affords a home to many species of raptorial birds. But the vultures of Mount Tilla are a favoured race: they look down upon the field of Chilianwalla, only ten miles distant, where their more immediate ancestors must have had a glorious feast. And, indeed, there may be traditions of a still greater banquet, when Alexander the Great crossed the Hydaspes by stratagem, and defeated Porus within a short distance of the same spot.

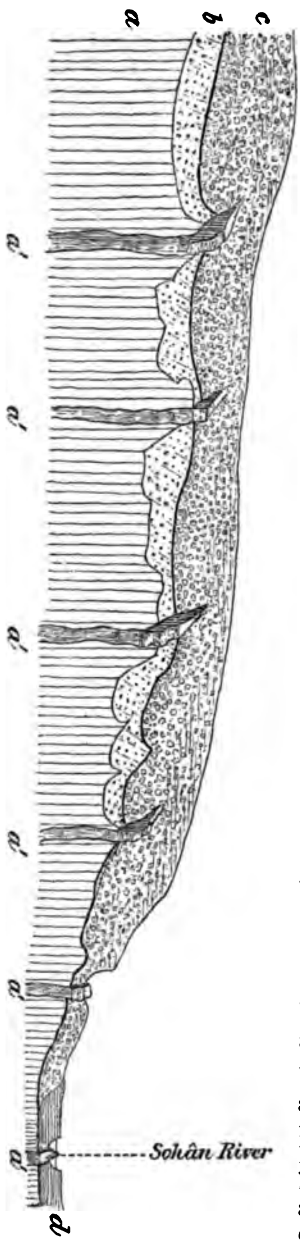


FIG. 3.—HIGH-LEVEL ALLUVIUM AND GRAVELS OF THE SOHAN VALLEY.

a. Soft Sandstones of the Siwalik beds.
a'. Harder grits of the same series with bones and teeth of mammals.
b. The soft Sandstones decomposing *in situ*.
c. High-level (Pleistocene) Alluvium and Gravels.
d. Recent deposits of the Sohân river.

Pindi, we have a very instructive section, which combines, to a certain extent, the features of the plateau with those of a river valley, such as originates in the outer Himalayas. The Siwaliks are perfectly vertical at this place, and the harder grits stand up like so many trap-dykes, one of which may be seen in the bed of the Sohàn itself. Between these harder grits the softer Siwaliks are decomposing rapidly at the edges, but the *débris*, being more readily removed, does not accumulate so much as on the plateau. These vertical dykes are certainly fossiliferous, and I exhibit a tooth of *Mastodon* and some fragmentary bones which were lately procured from them. In some places, where the superficial beds are thin, these pseudo-dykes project beyond the general surface-level like the ribs of some gigantic skeleton. The strike of the beds here is W. half S., and at Riwat, on the plateau, about S.W. These strikes, it should be observed, are nearly at right angles to the normal strike of the North-western Himalayas, the roots of which are only a few miles distant.

The superficial deposits in the Pindi district are of great interest and importance. In places they are so thick as to bury the Siwaliks on which they rest. This is particularly the case in one of the tributaries of the Sohàn, where the appearances are so striking that I induced the local photographer to take two pictures, copies of which are now on the table. The alternation and thorough inosculation of bedded alluvium with gravels is a feature which I have noticed not only in the Pindi district, but also in the valleys of the lower portion of the Hazára. In the Sohàn and its tributaries the bulk of the gravels consist of hill-limestone of Lower Tertiary age, and of the harder parts of the Murree beds, which are of Middle Tertiary age. It should be borne in mind that the farthest sources of the Sohàn do not extend beyond the Murree Ridge, and are therefore wholly within Tertiary or Mesozoic rocks, which, as far as I know, are completely free from igneous intrusion within the basin. The presence of pebbles of Diorite is therefore not easy to account for.*

The general opinion with regard to these high level river gravels is that they are of Pleistocene age, and certainly they must be of considerable antiquity, when we bear in mind how deeply they are excavated by the present rivers, which have been denuding rather than depositing in this area for a long period. Though not very fossiliferous, remains of the elephant are occasionally found in them, and I am able to exhibit a portion of a tusk which Dr. Aitchison and myself disinterred from gravels about 70 feet above the bed of the Sohàn. The breadth of the base of this tusk seems to distinguish it from the existing elephant of India. Portions of the ivory in this case are much silicified, thus indicating remains of considerable antiquity.

There is also another point for consideration in connection with these horizontal Pleistocene beds, viz., their striking unconformity to the highly-tilted Siwaliks. This circumstance is by no means accidental, as one finds it to be the case in nearly all places where the two are seen in juxtaposition. The horizontality of these beds seems therefore to afford indisputable evidence that the oscillations which resulted in the upheaval of the Himalayas had terminated, in this area, at least, before the deposition of the gravels; probably the cessation occurred towards the end of the Pliocene period. I shall have again to notice this subject in connection with the gravels of the upper Jhelum. There has been an idea in some quarters, shared even by Falconer, that the uprise of the Himalayas still continues, and perhaps this may be so to a small extent, though I know of no evidence tending to substantiate this view. At any rate there cannot have been any material disturbance of the strata since the formation of these river gravels, and if the Himalayan system is still rising it must be *en masse*, so that the results of lateral pressure and differential

* See No. 3 in Appendix, p. 262.

elevation are not produced. It is true that the gravels near Rawal Pindi cannot in strictness be said to belong to the Himalayan system, but the same features are observable in the river gravels of the true Himalayan area, as I shall presently point out. Moreover, it is reasonable to suppose that the tilting of the Upper Tertiaries of the Siwalik Hills and of the Pindi Plateau, notwithstanding the difference of their strike, was due to the same cause, and occurred about the same period.

Rawal Pindi itself (1,700 feet) is situated on the uptilted Middle Tertiaries which are largely obscured in this neighbourhood by the alluvial gravel and earths which cover this upland plain. We made two excursions from this cantonment: one towards the *North-west*, viz., to Attock, Peshawur and Abbotabad; the other towards the *North-east*, which had for its object the valley of Kashmir.

There can be no doubt that the district between Rawal Pindi and Attock is one of great interest to the geologist, and, being traversed by a railway, is quite accesssible. The interesting station of Hassan Abdal would form a useful centre. The relations of the upland plateau to the ridges of older rock which intersect it hereabouts, the proximity to the higher ranges which are attached to the Himalayas, and the vicinity of the low-lying alluvial plain of the Indus and Kábul Rivers, constitute a rare variety of subjects which seems to provoke investigation. But to do anything here would have taken up far more time than was at my disposal.

On leaving Rawal Pindi we were told that there was nothing to see at Attock, and from this I drew favourable conclusions; nor was I disappointed, for the gorge of the Indus at Attock, with its surroundings, is one of the finest things we saw on the whole journey. A photograph of Attock lies on the table. Apart from the picturesqueness of the place and its historical associations, as the spot where the Indus has been crossed by almost every invader of India, the physical features are of peculiar interest. Why did the united waters of the Indus and Kábul Rivers, after flowing through the great plain which lies to the northwards, take the trouble to saw through this ridge of "Attock slate"? Of course, it is a question of levels, and the present level of the Indus at Attock is about 800 feet. Doubtless the drainage of the great plain of Peshawur must have escaped in some way, and that way, we may be sure, would be the easiest; yet when one looks at the gorge from the north, there seems to be a failure of the Attock chain to the eastwards, which might have afforded an easier escape for the accumulated waters of the Hindu Koosh and central Himalayas.

As regards the term "Attock slate," this covers a variety of rocks, and is a geological rather than a lithological term. Black, argillaceous limestone, for instance, with subconchoidal fracture,

like the specimen on the table, is not uncommon in the gorge of the Indus, and one sees argillites and even grits. An east and west strike seems to prevail hereabouts, but there is so much twisting of the beds that this could not be laid down as a fixed rule; neither is it clear that the beds correspond on opposite sides of the gorge, although in some cases they appear to do so. The same rocks, which are so blue in the river cliffs, weather buff in the upper parts of the hills. The river is pretty full of sediment, yellow with a greenish-grey tinge, and the bulk of the deposit is fine quartzose sand, with fragments of rock-crystal and flakes of variously coloured micas.

On leaving Attock we went to Peshawur and even as far as Jumrood at the entrance of the Khyber Pass, but the weather was so bad that I was unable to do anything in the way of observation. On our return towards India, after a night at Hassan Abdal, we set off once more in the direction of the frontier, and this time for Abbotabad, 44 miles to the northwards. It is in this direction that the last vestiges of the plains of India extend, running up like a tongue into the mountains of the Hazára, and mos interesting sections showing the relations of alluvium and ri gravel similar to those of the Sohàn Valley may be seen on t route. On crossing a wide river-course, where these Pleistoc beds are displayed to perfection, the road enters a mountain country which lies between the deep valleys of the Indus and t Jhelum. It is a question in orography whether these mounta belong to the Himalayan system or not. One might say from geological point of view that they are outside the prevailing nort west strike of the chain, which is deflected at the northernm angle of the Jhelum Valley near Muzufferabad. Since there something exceptional in the character of these mountains, I w draw attention to some points in the geology of the Abbotab district which have been so well elucidated by Messrs. Wynne ar Waagen.

On the first rise from the alluvial tongue before mentione we find ourselves in a confused mass of steeply-sloping mountain most of which would come within the category of "Attock slates" but as the road continues to ascend towards Abbotabad, a larg mass of grey limestone appears, the true relations of whic puzzled me very much at first, as I fancied it must be th ordinary hill limestone of Nummulitic age, which had bee faulted into the slates. During the two days we were at Abbo abad, I spent some time in searching this limestone for fossils, b without success, although I was rewarded by magnificent vie across the vale of Abbotabad (4,200 feet) in the direction of t northern snowy mountains.

The annexed diagram section (Wynne and Waagen) may se to convey some idea of the position of this limestone in ravine below Abbotabad, through which the road is carried.

anyone going away from Abbotabad, the limestone would appear on the left, as shown in the section (Fig. 4).

On studying their section I found that I had been exploring a great series of Triassic age, consisting of limestones, dolomites, quartzites, breccias, etc. Fossils are said to be by no means numerous, but the forms of *Megalodon* and *Dicerocardium* may be traced on weathered surfaces; and there are probably other indications of the Triassic age of the beds, though I am not aware that Ceratites have been found. Below these Triassic beds occurs an unfossiliferous system, which, it is thought, may be Carboniferous, and the whole series is completely unconformable to the "Attock slates." But the marvels of Mount Sirban are by no means exhausted since we perceive on the other side of the fault, below

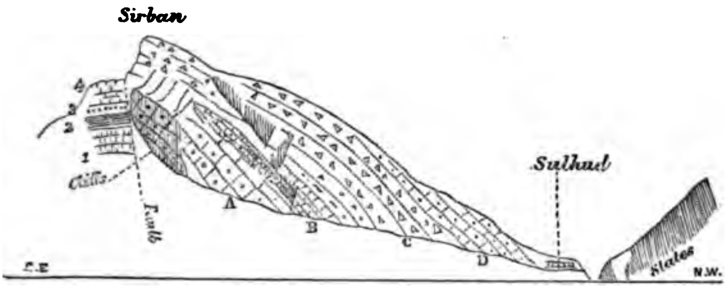


FIG. 4.—MOUNT SIRBAN, 6,243 FT., NEAR ABBOTABAD.—*After Wynne and Waagen.**

D.	Dolomite	Trias.
C.	Thick quartzites and breccia . . .	Trias.
B.	Thin-bedded limestone with some fossils .	Trias.
A.	Dolomites	Trias.
4.	Nummulitic Limestone	Nummulitic.
3.	Cretaceous zone (fossils)	Cretaceous.
2.	Spiti-shales (fossils)	Jurassic.
1.	Limestones	Triassic.

* *Mem. Geol. Surv. India*, vol. ix (1872), p. 345.

the summit, a complete series of Mesozoic rocks, including the Nummulitic. It is thought that there is an unconformity here, between the Spiti-shales (Jurassic) and beds of Triassic age; so that there are two distinctly recognised unconformities. The Mount Sirban section will also serve to show how the formations are broken up in these mountains, and it may help to give an idea of the character of the surface in the Abbotabad district.

Towards the latter end of March our preparations for the long-projected journey to Kashmir were complete, but we were detained by bad weather at Rawal Pindi for three or four days; and when at length we started on the morning of the 26th, there were predictions that we should not get through, as the new cart-

road in the Maharajah's territory was reported to be broken down in many places.

There is a drive of about twelve miles in a north easterly direction across the plateau ere the roots of the Himalayas are reached. This part of the upland plain is formed by the Middle Tertiaries or Murree beds tilted at high angles, but covered with so thick an alluvium that no rock is visible until within three or four miles of the foot of the mountains, when the usual rib-like structure appears through the skin. All the ridges in the low ground are of sandstone, with hollows representing the softer beds, and the prevailing strike near Shanurpore is S W., with high dips to the N.W. This, I believe, is the place where Mr. Wynne gives the section (reproduced in Fig. 5) showing the roots of the North-west Himalayas as they emerge from the Pindian plain.

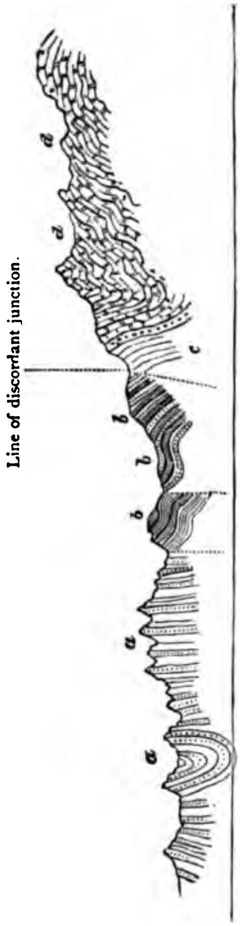


FIG. 5.—GENERALISED SECTION AT SHAHKA-NOORPOOR. (Length about 3 miles; highest hills 4,000 feet).—*After Wynne.**

a Murree Beds.
b Limestone bands (Nummulitic), gypseous red and greenish-grey shales.
c Jurassic Limestone.
d Hill-Limestone (Nummulitic).

* *Quart. Journ. Geol. Soc.*, vol. xxx, p. 71.

Within short distances a considerable difference might be observed in the junction-sections between plateau and mountain, but they nearly all exhibit this peculiarity viz., that in the neighbourhood of the fractures, whilst the beds of the plain are almost vertical, those of the mountain roll over at comparatively easy angles. Of course, this feature is not maintained in all cases; moreover, the Murree beds themselves soon become involved in the Himalayan uplift. and are quickly raised to heights of over 7,000 feet, as on the Murree ridge.

I had been at some pains a few days previously to note these facts, but, on the present journey, no delay was advisable, and it was necessary to be content with impressions as derived from the

tonga, which halted at Tret for the night. We were now fairly in the outer Himalayas, amid beds of Lower and Middle Tertiary age exclusively, and when we pursued our journey towards the Murree ridge in the morning we had the Nummulitic Limestone country on our left, and the massive grits of the Murree beds on our right. The contrast in the scenery is fairly well marked, but throughout this immense region of Lower Tertiaries, which attain elevations of not less than 9,000 feet, there is a certain degree of sameness in the landscape, such as we had previously noticed during our drive to Simla. Amidst an endless maze of V-shaped valleys and precipitous slopes, no peak distinguishes itself from its fellows, and no precipice overawes by its mural character. After such heavy rains waterfalls ought to have been conspicuous, but, owing to the want of horizontality in the beds, and, possibly, to other causes, they seem to be very scarce in this region. Two strikes, which I took at Murree, bear S. half W. and S.S.W., so that we are not yet within the true Himalayan system, although the elevation exceeds 7,000 feet. The grits and clays of the Murree beds are naturally well-wooded, although at great elevations even the limestones on the "Gully" ridge carry a considerable amount of timber. As we continued to ascend from Tret towards Murree, it is interesting to notice that *Pinus longifolia* is almost entirely replaced by *Pinus excelsa*, and on Pinnacle Hill, where the exterminating axe of the native cultivator has been restrained for a while, these pines are reinforced by a goodly show of the tall Himalayan spruces. There are no deodars (*Cedrus deodara*) here, and I may remark, by the way, that I never saw a deodar growing on any beds of Tertiary age.

A drop of 5,000 feet brings us to the bottom of the Jhelum valley, which at Kohála is about 2,000 feet above sea-level; the river here is a furious rapid rushing along in its narrow rock-bed. The tortuous course of this river valley we now had to follow in its ascent of about 3,000 feet, to Baramula. The first section of the journey runs due N. as far as the angle of the Jhelum, at Muzufferabad (Domel), and on the east side of the river, where the road lies altogether in the Murree beds. The second section runs S E. from Muzufferabad to Uri, and also lies wholly in the Murree beds. The third section runs E.N.E. from Uri to Baramula, cutting right across the axis of the Panjal range, and is mainly within the area of slaty and schistose beds—the "Attock slates" or Cambro-Silurian of the Survey, and the Panjal system of Mr. Lydekker.

It was almost fortunate that I did not possess a Kodak, or we should have tried the temper of our tonga-drivers by perpetual halts to photograph the fine sections which this gorge-like valley affords. I am only too conscious that mere verbal description is altogether inadequate to convey a proper idea of these scenes. A few words respecting the Murree beds may not be altogether

out of place. Massive purple grits and clays are the predominating feature, and the grits are often seamed with calcite, as in the case of the specimen exhibited. It is strange that such an immense mass of beds should be so unfossiliferous; but hitherto the only organism identified is a palm of Miocene age—*Sabal major*—found by Mr. Lydekker in the middle section of this route. So much for the palæontology of these beds, which may be held to represent the first deposit within the area after the commencement of the Himalayan uprise, and which themselves now form an outer portion of that mighty range with ridges not far short of 10,000 feet in elevation.

You perceive from the map how curiously the Jhelum is doubled back on itself. I rather think there is a sort of synclinal between these two great arms of the river, and that the river bed itself in the first and second sections lies in anticlinal. At any rate, I noticed, as we were being driven along the Kashmir cart-road, that there is a considerable tendency for the beds to dip inwards, both in the first and second sections, and to this cir-

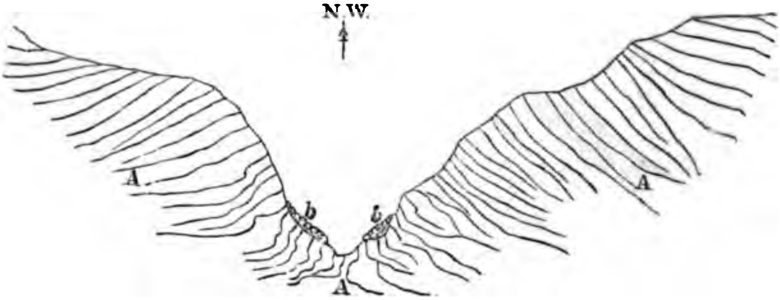


FIG. 6.—IDEAL SECTION ACROSS THE JHELUM VALLEY, BETWEEN MUZUFFERABAD AND URI.

A. Murree Beds (Miocene).
b. Pleistocene Gravels.

cumstance the preservation of the road is to a certain extent due. For we must acknowledge that nature does not altogether look with favour upon this cart-road, and that in places where undercutting has been extensively practised, if the beds happen to be clayey or there is a lot of slippery talus, the pitch of the slopes is so steep that, after heavy rains, a glacier of mud and stones is formed across the track, which is thus either masked or carried away altogether.

The annexed diagram (Fig. 6) may partly serve to illustrate [illegible] notion of that portion of the Jhelum valley which lies wholly within the Murree beds, and is more especially applicable to the middle section between Muzufferabad and Uri. It will be seen that the

beds in the lower portion of the section lie at a much higher angle than those in the upper portion. Of course this is only an impression as seen from a tonga, but of its substantial accuracy I have no doubt. Mr Lydekker, in his Memoir on the Kashmir territory, notices that the lower beds in the valley gorges are often more highly tilted than those on the hill-tops; and he goes on to say that this has been explained on the supposition that a considerable amount of the contortion occurring in the strata has taken place since the present hills and valleys were marked out. I cannot quite understand this, and would much rather believe the phenomenon is due to differential pressures acting approximately at the same time, whereby the upper beds being less weighted, and having more room to expand, gaped at the surface, and fell away from the axis of tension in dips of moderate degree. Lower down no such relief could be afforded, and we have the beds standing on end, and in every attitude; though even here they are rarely contorted, and, so far as I know, not in the least degree metamorphosed. If my notion of gaping at the surface is correct, such a feature would largely help to determine future lines of drainage.

The third section of the road, viz., that between Uri and Baramula, running right across the strike of the beds and more especially of the Panjal system with its associated Metamorphic and Igneous rocks, presents totally different features and exhibits on the whole more impressive scenery. This is a transverse valley, due in the main to denudation, yet clearly determined by a weakness in the Panjal axis, since the granitic and other crystalline rocks, which form this conspicuous crest of the Himalayan system fail at the point where the Jhelum crosses, so that the gorge lies wholly within the schistose rocks, which are probably of Palæozoic age. The scenery is truly magnificent, and precipices of the schist* tower above the small station of Rampur in the most impressive manner. Here also deodars figure largely in the hanging forest of the region, flourishing on Palæozoic rocks just as at Simla. This must be an excellent place for examining the effects of strain in rocks, as one of the sharpest and best marked of the Himalayan anticlinal axes has been cut through by the Jhelum at Rampur,† which station lies about half way between Uri and Baramula.

Irrespective of these considerations, the locality is full of geological interest. On referring to Fig. 6, it will be seen that, in the second section of the route, the Jhelum has cut through a terrace of Pleistocene gravels. This terrace is perhaps still better developed in the third or Rampur section, though I am not sure

* No. 4 in Appendix, p. 263.

† No such place is marked on the maps. The station bearing this name lies on the south side of the Jhelum, immediately west of its junction with the stream from the south, marked in Lydekker's map as the "Harpatkai" River, but which in Murray's handbook goes by the name of the "Haji Pir" River; the temple of Bhaniar is on the opposite side.

of its having been cut through in all cases. Practically, however, there is more or less of a gravel terrace on the banks of the Jhelum all the way between the commencement of the gorge near Baramula and Muzufferabad. Fine sections of this old river gravel are occasionally displayed by the road cuttings, and it is worthy of note that these sections are, in many places, quite vertical, showing how well the boulders cohere. Occasionally a boulder much bigger than the rest projects from the vertical face and seems to threaten destruction to the tonga and its occupants. This is more especially the case in the second section, near Chakoti, and, although on the whole the cuttings in the gravel were less effected by the recent heavy weather than those in the Murree beds, yet when one of these big boulders did happen to fall out, the appearances were somewhat alarming.*

One cannot help being struck by the contrast between these horizontal boulder beds, and the highly tilted rocks on which they rest. Just as in the Sohàn Valley, this fact seems to me conclusive against any important movements having taken place within the area since the commencement of Pleistocene times. True, the area is an uneasy one, and the earthquake of 1885, which utterly destroyed Baramula and wrought such havoc in Kashmir City, will serve to remind the dweller in the Himalayas of the instability of the ground beneath him. Yet such earthquakes seem to have produced no very obvious results in disturbing the almost horizontal gravels of the Jhelum gorge, at and below Rampur.

A word or two as to the composition of these Jhelum gravels may be interesting. In the second section of the route a cursory examination indicates that the hard parts of the Murree beds have contributed a large proportion; hence the gravels are mainly of local origin. But, when only a few miles above Muzufferabad, I noticed a granite boulder with large porphyritic crystals of white felspar, and this kind of rock became more plentiful as we proceeded up the valley, though I could not pretend to say that it is to be traced throughout. However, when we got to Rampur, I took a stroll, with my wife and General de Bourbel, to the junction of the Jhelum with the Haji Pir River. Here we found an enormous accumulation of these granite boulders, many of them of gigantic size, embedded in a sort of terraced, clayey deposit, which looked uncommonly like a rearranged moraine. The Haji Pir River drains a valley at right angles to the course of the Jhelum, and this valley must nearly coincide with the Panjal axis. Hence we may conclude that there is an important exposure of granite somewhere along this axis which has yielded these boulders. The beautiful old Hindu temple of Bhaniar has been constructed of stone supplied by

* Early in April last, as the Resident of Kashmir and his wife were travelling by this route, one of these big boulders fell just in front of them and greatly alarmed the lady. Undoubtedly they had a narrow escape.

these boulders, and the builders seem to have selected those with conspicuous crystals, some of which are half a foot long. Above Bhaniar one no longer sees this granite in the gravels. Mr. Lydekker notices the granite boulders, but seems disposed to derive them from the north side of the Jhelum.*

One cannot help drawing some inferences from these gravels and their mode of occurrence. In the first place it may be objected that to call them "Pleistocene" is an assumption. Yet they must be of considerable antiquity, when we perceive that the Jhelum has not only cut through them, but also, in some places, through a considerable thickness of the underlying rock. Moreover, the action of the river must have been very different during the period of accumulation from what it has been subsequently; and yet all these changes have taken place since any marked disturbance has occurred within the area. It is by no means improbable that the accumulation of the gravels coincided with the period when there was some glaciation on this side of the Kashmir Valley. This seems to be Mr. Lydekker's opinion. The point is of importance, as helping to fix the date when the movements in connection with the uprising of the Himalayas ceased. There is some additional evidence on this point, afforded by the superficial deposits known as Karéwas, which skirt the interior slope of the Panjal range facing the Vale of Kashmir. Mr. Lydekker, in his map, classes these as Pleistocene; and it is significant that, while the lowest and oldest beds exhibit a certain amount of tilting, the bulk of these Karéwas are nearly horizontal. Hence the movements were dying out when the Karéwas first began to be deposited, just as was the case with the topmost Siwaliks of the outer hills.

As regards the granite itself, it is no doubt derived from a mass on the crest of the Panjal, which has been squeezed through the crystalline axis, and, according to my notions, is most probably of Tertiary age.

Continuing our journey from Rampur, the gorge of the Jhelum gradually becomes less savage, and a wide expansion towards the east seemed to proclaim that some great change in the landscape was impending. We had now got through the Panjal chain, but all view of the land of promise was still blocked by a low range, part of which, probably, consists of the aforementioned Karéwa deposits. There are two ways from here to Baramula. The new cart-road follows the natural cutting afforded by the Jhelum, whilst the old track takes a short cut over a low col. We chose the latter on account of the view which it commands, and which has been celebrated by many travellers. There lay at our feet the western half of the Vale of Kashmir, and owing to the enormous expansion of the Wular Lake, the low ground appeared to be one vast inundation. Right across this depression

* For a description of this granite see No. 5 in Appendix, p. 263.

rises an enormous mountain rampart, forming a portion of the central Himalayas. Exactly opposite are the rocky masses of Haramuk, rising to a height of 17,000 feet, and this chain extends to the right and left as far as the eye can reach. The Tragbal Pass leading to Gilgit is very obvious, and in this direction some of the party fancied that they could perceive the peaks of Nanga Parbat (26,629 feet), the monarch of the North-west Himalayas, which bears nearly due north from this spot, seventy-five miles distant.

We must now consider our position on this low col above Baramula from a physical point of view. Regarding the rocks of the Kashmir basin and of the Panjal range as a whole, Mr. Lydekker says there are two principal anticlinal axes: First, that of the Panjal itself, which exposes disconnected portions of a central crystalline core, and right athwart this axis lies the gorge of the Jhelum that we had just traversed. The second anticlinal is exactly opposite to us, viz., the mountain range on the northern side of the Wular Lake, of which the rocks in the neighbourhood of Haramuk form the south-eastern termination. As regards the chief synclinal axes of the area, these must be sought (1) in the Mesozoic rocks of the outer hills; (2) in the Kashmir Valley itself; and (3) in the district on the other side of the Haramuk range, where beds of the Carbon-Trias or Zanskar system of Lydekker are folded within the older palæozoic series. To put it more plainly, the Vale of Kashmir constitutes an elongated oval synclinal area, about ninety miles in length, where beds of Carboniferous, Triassic and possibly Jurassic age lie within a ring of older palæozoic rocks; these latter have been denominated the Panjal system, corresponding in the main to the "Attock slates," or Cambro-Silurian of the Survey.

There are so many points of interest in connection with the Vale of Kashmir that one might well devote a paper solely to their consideration. To some of these I must merely allude. For instance, the question of the exit of the Jhelum at Baramula, and its bearing on the existence of a former lake has given rise to much discussion. The history of the Karéwas, or Pleistocene deposits of the Vale, which are banked up in large masses against the northern slopes of the Panjal, also affords considerable matter for speculation; fossils appear to be by no means plentiful, and there seems to be a doubt whether the deposits are fluviatile or lacustrine. Perhaps one of the most remarkable features of Kashmir is the oval ring of palæzoic volcanic rocks which, according to Lydekker's map, surrounds the Vale. Those on the northern side come right down to the marshy flat which constitutes the Vale proper, rising out of the plain like islands. The picturesque rock near Manasbal, at the entrance of the Sind Valley is one of these; but by far the most interesting development is at Srinagar itself, whose position has been determined by

a promotory of these andesitic traps, which separates the marshy basin of the beautiful Dal Lake from the plain of the Jhelum. This promotory finds expression in the low hill of Hari Parbat, crowned by the fort and state prison, and by the picturesque and conical Takht-i-Sulimán, which rises a thousand feet above the plain, and is crowned by an old Hindu temple.

I submit two specimens of the igneous rock of Srinagar, both from the lower portion of the Takht-i-Sulimán: the one is close-grained, and the other vesicular. The former has been examined by General McMahon,* who says that the rock has been altered almost out of recognition, but that it was probably in its original state an augite andesite. Both specimens are greatly epidotised, but may fairly be regarded as products of the same magma which have cooled under different circumstances. The period of extravasation is variously stated as uppermost Panjal (Silurian) or Carboniferous, but at any rate Palæozoic. Hence the present thermal activity in the Vale, which was first noticed by Falconer in 1838, can have little or no connection with these eruptions; nor can I ascertain that there is any igneous rock of later date to be found *in situ* in the Vale.

We owe to the traveller, Vigne, in 1842, the recognition that the mountains about Srinagar were composed of amygdaloidal trap, though Mr. Lydekker was probably the first to point out the geological relation of these beds. In the neighbourhood of the Takht-i-Sulimán there is a low col on the east side leading to the Dal Lake, where certain splintery shales may be seen; and these are said to be partly inter-stratified and partly to underlie the igneous rock. The Col itself occurs in these shales, whose softer nature has determined this well-marked hollow. All the steep, eastern side of the beautiful Dal Lake, says Mr. Lydekker, is a mixture of these slates and volcanics. Hence the presumption that the igneous rock is not intrusive; he finds no necks or dykes, and yet doubts their being the result of fissure eruptions. General McMahon has stated his opinion that these rocks are old altered lavas, similar to those found in the neighbourhood of Dalhousie. From this conclusion we can scarcely dissent; and it seems probable, owing to the abundance of amygdaloidal beds, that the lavas were poured out on a terrestrial surface. There is, of course, the usual difficulty as to where the vents existed, and if it were not for the vesicular character of part of the beds, one might be disposed to regard the Takht-i-Sulimán itself as an old volcanic core. However, these and many other points of equal interest must be left for the present, and this brief notice of the Vale of Kashmir must terminate.

* No. 6 in Appendix, p. 264.

APPENDIX ON THE ROCK-SPECIMENS.*

By Lieut.-Gen. C. A. McMAHON, V.P.G.S., President.

No. 1.—Bundelkhand Gneiss, Jhánsi.

The thin slice of this rock, prepared for the microscope, contains the following minerals, viz., quartz, orthoclase, microcline, some acid plagioclase, a little dark mica, and magnetite. The latter mineral is rather abundant. Here and there the slice contains ferrite, and in some places it is stained red with ferric oxide.

There are no traces of a foliated structure under the microscope.

The quartz contains numerous liquid cavities with movable bubbles. The latter are rather large as compared with the size of the cavities containing them, a fact which indicates the existence of considerable pressure and heat at the time the liquid was imprisoned in the quartz. Some of these cavities contain crystals deposited during the cooling of the liquid.

Under the microscope the rock has all the aspects of a true granite, and although its genesis may have been in archæan times, I cannot doubt its igneous origin.

No. 2.—Granite, Mount Abu.

This slice contains quartz, orthoclase, microcline, a little acid plagioclase, biotite (which is rather abundant), ferrite, and some chlorite.

The felspar contains two or three crystals of quartz with hexagonal outlines and a good many secondary products, such as blebs of quartz, mica, ferrite, and chlorite.

The quartz is broken up into micro-grains, many of which present a distinct tendency to exhibit polygonal and hexagonal outlines, and recalls the tessellated quartz in the granite of the N.W. Himalayas. The quartz has occasionally eaten into the felspar, and the idea suggested to my mind by the relationship of the two minerals is that, at one stage in the history of the rock, there was a partial remelting of its component minerals.

The quartz shows liquid cavities with movable bubbles, and some of these cavities contain deposited minerals. The cavities, however, are sparse, and the bubbles minute. Whatever its age may be, this is, in my judgment, a true granite.

No. 3.—Diorite, Gravel of the Sohan.

This slice is composed of felspar and hornblende. The felspar is highly altered. It is dull white in reflected, and absolutely opaque in transmitted light. Here and there it includes an irregular-shaped colourless mineral, which is probably water-clear secondary felspar.

* These and others were exhibited at the Meeting of 6th December, 1895.

The hornblende is of a type very common in the epidiorites of the N.W. Himalayas. In transmitted light it ranges from a dark blue-green to a pale brown-yellow-green or greenish-yellow. It is powerfully dichroic, and the cross cleavages are well marked. It contains a colourless mineral in stumpy prisms, which shows occasional traces of polysynthetic twining. At first sight it looks like a triclinic felspar; but here and there it is distinctly dichroic, changing from colourless to green; and its refraction is higher than that of the hornblende. I think it is a white pyroxene.

In structure the rock is granitic.

No. 4.—Schist, Rámpur in the Jhelum Valley.

This fine-grained rock consists of two kinds of mica, with the remains of some comparatively large felspars, set in a quartz base. One of the micas is of a rich, dark, greenish-brown colour. It is strongly dichroic, and is in comparatively large flakes, or leaves, which do not exhibit any cleavage. The other, probably a hydro-mica, is almost colourless in transmitted light. It is in minute, irregular-shaped patches, or scales, and is matted together in bands, which exhibit a decided fluxion structure. The intermediate bands are formed of larger grains of quartz. The dark mica is common to both bands, and shows a tendency to form distinct strings.

The remains of several large felspars are rounded as if by the corrosive action of an acid base. One of them is visibly triclinic, but it is impossible to say whether the others are orthoclase or plagioclase.

The rock has evidently been subjected to considerable pressure, for the orientation of the leaves of mica indicate the setting up of a cleavage foliation which runs at various angles, often high, to the lines of fluxion.

An examination of a single specimen, only, is not sufficient to enable one to say, with any confidence, what the rock was originally before it was turned into a schist. It may have been an argillaceous sedimentary rock, a volcanic ash, or a rhyolitic rock.

No. 5.—Porphyritic granite, Jhelum Valley.

This slice contains quartz, orthoclase, microcline, plagioclase (probably oligoclase), biotite (which is abundant), muscovite, a little magnetite, and ferrite. The plagioclase predominates over the orthoclase and microcline, but the slice may not be a fair sample of the rock as a whole.

The muscovite is intergrown with the biotite, and both appear to be original minerals.

The felspar and quartz contain colourless crystallites and micro-crystals, the exact nature of which cannot be determined. Some of the latter, like those in true typical granites, contain fixed bubbles, and liquid cavities with bubbles. The liquid cavities in the free quartz are small.

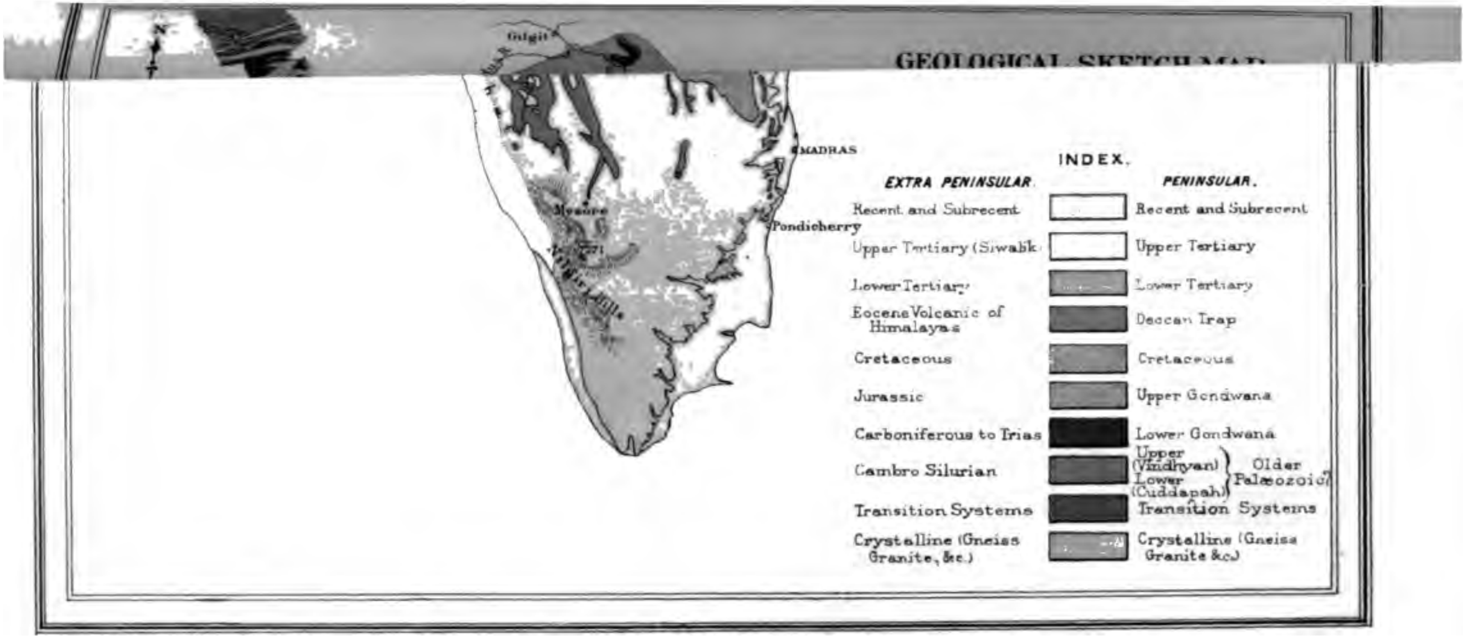
Some of the quartz is micro-granular in structure, like that of the Dalhousie rock. This granite is doubtless a N.W. extension of that of the Dhular Dhar. I presume that the specimen was taken from a block derived from the mountains of the Pir Panjal.

No. 6.—Basic igneous rock, Takht-i-Sulimán Hill, Srinagar, Kashmir. The specific gravity of the hand specimen is 2·81.

Much of the ground mass, viewed between crossed nicols, remains quite dark, owing to the production of secondary minerals inert in polarised light. Remains of lath-shaped plagioclase, and brown pseudomorphs after augite, can be made out. There are also numerous grains of epidote, colourless in transmitted light, which doubtless is a secondary product of decomposition. The slice does not contain any serpentine, and there is nothing to show the former presence of olivine. This rock has been altered almost out of recognition; but I think it was probably, in its original state, an augite-andesite.

C. A. McMahon.

16*th November*, 1895.



Mintern Bros. lith. London.

ANNUAL GENERAL MEETING.

FEBRUARY 7TH, 1896.

LIEUT.-GEN. C. A. McMAHON, F.G.S., President, in the chair.

Mr. KENNEDY and another were appointed Scrutineers of the ballot.

The following Report of the Council for the year 1895 was then read:

THE numerical strength of the Association on the 31st of December, 1895, was as follows:

Honorary Members	16
Ordinary Members:	
a. Life Members (compounded)	159
b. Old Country Members (5s. Annual Subscription)	7
c. Other Members (10s. Annual Subscription) .	350
Total	532

During the year twenty-nine new Members were elected.

The Council regrets that the Association lost eight members by death: J. Whitaker Hulke, Edmund Edwards, Francis E. Brown, J. M. Coates, A. O. Robinson, Dr. H. J. Wharton, Hyde Clark, and W. Clark. Mr. Hulke, equally eminent in surgery and in vertebrate palæozoology, was more often seen at your excursions than at your evening meetings. His works, characterised by singular clearness and remarkable accuracy, have thrown a considerable light on the interpretation of the fossil Reptilia. He was devoted to his profession, and, indeed, his death resulted from a chill contracted during a night visit to the Middlesex Hospital in the bitter weather of last February.

Omitting the *Record* and *Paris Basin*, the income of the Association for 1895 was £248 19s. 3d., showing a substantial increase on last year's figures; while the expenditure, £228 10s. 1d., is rather less than last year, a saving which has been effected almost entirely in the office expenses. It is gratifying to find that the falling off in the receipts last year was only temporary, every single item this year showing an increase, and your Council has been able, after handing over a sum of £25 to your Trustees for investment, to carry forward a balance of £19 19s. 4d.

GEOLOGISTS' ASSOCIATION.

Dr. Income and Expenditure for the Year ending Dec. 31st, 1895. Cr.

Dr.	£	s.	d.	Cr.	£	s.	d.
To Balance from 1894	16	3	0	By Printing "Proceedings"	105	2	2
" Life Compositions	25	10	0	" " Monthly Circulars	17	14	6
" Admission Fees	15	0	0	" Illustrating "Proceedings" and Circulars ...	16	15	9
" Annual Subscriptions	176	15	0	" Miscellaneous Printing	3	18	0
" Dividends on Nottingham Corporation Stock ...	23	9	6	" Postages	38	1	1½
" Sale of Publications	8	4	9	" Addressing	7	16	0
" Sale of "Record"	7	2	6	" Library	5	11	11
" Sale of "Paris Basin"	1	4	8	" Attendance, Gas, Lantern, etc., at Evening Meetings	19	9	6
				" Excursions	9	18	10½
				" Insurance	1	10	0
				" Stationery	2	1	1
				" Miscellaneous Expenses	0	11	2
				" Purchase of £22 19s. 7d. Nottingham Corporation Stock, and Broker's Commission ...	25	0	0
				" Balance at Bank of England, Dec. 31st, 1895...	19	19	4
	£273	9	5		£273	9	5

We have compared the above account with the vouchers and find it to be correct.
We have also verified the investment of £820 16s. 10d. Nottingham Corporation Stock.

January 10th, 1896.

JOHN HOPKINSON, }
A. E. SALTER, } *Auditors.*

The receipts from advertisements having been steadily falling off for the last few years, your Council appointed a Committee to consider whether the PROCEEDINGS could not be made use of, as in the case of many other Societies, as a permanent source of revenue, with the result that a contract was entered into with Mr. McVeagh, letting to him, under certain restrictions, the right to use the last three pages of the cover, and as many other extra pages as he can fill, for the purposes of advertising. Your Council hope that the profits thereby accruing to the Association will compensate for what might perhaps be considered by some members a disfigurement to the PROCEEDINGS. The fact that nothing has been received on this account in 1895 is due to the first payment by Mr. McVeagh having been fixed for January, 1896.

During the year the usual five numbers of PROCEEDINGS have been published, consisting of 208 pages, with six plates and forty-five illustrations in the text. You are indebted to Mr. H. J. Osborne White for Plate I, to Mr. H. W. Monckton for Plate III, and to Mr. G. F. Harris for Plate IV. The title-pages, contents, and index of Vol. xiii were also issued early in the year.

The library continues to be increased by the addition of many valuable works received either as donations or in exchange for the publications of the Association.

The Bulletins of the Geological Survey of the United States of America have been bound in twenty-one volumes, and are thus rendered more accessible to members. A very large proportion of these Bulletins, like the Memoirs of the same Survey, deal with subjects of more than local interest, and it is believed that they only require to be better known to be in greater request by readers.

Your thanks are again due to Mr. Henry Fleck for continuing to assist in the work of the library.

The following is a list of the papers read at the evening meetings:

"On the Analysis of Oolitic Structures," by G. F. HARRIS, F.G.S.

"The Geological History of the Himalayas," by GENERAL MCMAHON.

"The High-Level River-Drift between Hanwell and Iver," by J. ALLEN BROWN, F.G.S.

"The Necessity for Competent Geological Surveys of Gold Mines," by NICOL BROWN, F.G.S.

"Sketch of the Geology of County Antrim," by A. MCHENRY, M.R.I.A.

"The Mourne Mountains," by R. LLOYD PRAEGER, B.E., B.A.

"Notes on Indian Geology, including a visit to Kashmir," by W. H. HUDLESTON, M.A., F.R.S.

Lectures were delivered by Mr. Lazarus Fletcher, F.R.S., "On Meteorites," and Mr. W. F. Gwinnell, F.G.S., "On the Rocks and Scenery of Western Norway." Your thanks are due to these gentlemen.

A conversazione of a most successful character was held in November. A full list of the exhibits will be published in the Report for that evening in the PROCEEDINGS, and your thanks are due to those members who assisted towards the success. Never before in these rooms has so excellent an opportunity for a study of flint weapons of all ages been offered as was given by the combined collections of Mr. E. T. Newton, Dr. Corner, Mr. Elliott, Mr. Allen Brown, and others.

The following Museums were visited during 1895:

The Rock Gallery of the Museum of Practical Geology, Jermyn Street, on March 23rd, when a demonstration on British Rocks was given by Mr. W. W. Watts, M.A., F.G.S.

Colonel Bevington's Museum, at Sevenoaks, Kent, on August 24th.

The following is a list of the excursions made during the past year; detailed reports will be found in numbers iii and v of vol. xiv of the PROCEEDINGS.

DATE.	PLACE.	DIRECTORS.
March 30th.	Hampstead.	A. M. Davies, B.Sc., F.G.S.
April 12th to 16th (Easter).	Isle of Wight (Tertiary Beds).	R. S. Herries, M.A., F.G.S., and H. W. Monckton, F.G.S.
April 20th.	Charlton.	T. V. Holmes, F.G.S.
April 27th (whole day).	Brigstock and Geddington.	B. Thompson, F.C.S., F.G.S., and W. D. Crick, F.G.S.
May 4th.	Hanwell, Dawley, and West Drayton.	J. Allen Brown, F.G.S.
May 11th.	Chilworth and Woodhill.	J. W. Gregory, D.Sc., F.G.S.
May 18th.	Betchworth and Headley.	H. W. Monckton, F.G.S., and W. P. D. Stebbing, F.G.S.
May 25th (whole day).	Goring.	J. H. Blake, F.G.S., and W. Whitaker, F.R.S.
June 1st to 4th (Whitsuntide).	Banbury.	E. A. Walford, F.G.S.
June 8th.	Chelmsford.	T. V. Holmes, F.G.S.
June 15th.	Tilburstow Hill.	T. Leighton, F.G.S.
June 22nd.	Totternhoe.	W. Hill, F.G.S.
June 29th (whole day).	Burham and Aylesford.	C. Bird, F.G.S., and W. F. Hume, D.Sc., F.G.S.
July 13th.	Eynsford and Wrotham.	W. J. Lewis Abbott, F.G.S.
July 20th.	Tunbridge Wells.	R. S. Herries, F.G.S., and G. Abbott, M.R.C.S.
July 29th to August 3rd (long excursion).	Belfast and Coast of Antrim.	A. McHenry, M.R.I.A.
August 24th.	Sevenoaks.	W. J. Lewis Abbott, F.G.S.

The interest of members in the excursions of the Asso-iation during the past year has been fully maintained.

The welcome accorded to the Association by the geologists of ne North of Ireland was hearty in the extreme. You are much ndebted to the Belfast Naturalists' Field Club, and to its officials, or the success of this meeting. A word of praise for peculiar nterprise is due to the directors of "The Belfast and Northern Counties Railway Company" for the publication for free dis-ribution, in special reference to the visit of the Association, of a eological handbook entitled, *Scenery and Geology in County Antrim*, written by our friend and member, Prof. Grenville A. J. Cole, M.R.I.A., F.G.S. Your thanks are due to the Company or the copies presented to members of the excursion.

Your thanks are due to the directors of the excursions; also to he following ladies and gentlemen for assistance and hospitality: Mr. W. W. Watts, M.A., F.G.S., on March 23rd; Mr. Titus Barham, at Hampstead: Mr. G. W. Colenutt, F.G.S., and Mr. J. Dace, in the Isle of Wight; Mr. T. V. Holmes, F.G.S., and Mrs. Holmes, on April 20th; Mr. and Mrs. Stebbing, at Headley; Mr. Miller Christy and Miss Christy, at Chelmsford; Mr. J F. Bigger, M.R.I.A., Prof. G. A. J. Cole, M.R.I.A., F.G.S., Mr. . C. Howarth, of the Eglinton Chemical Company, Ltd., Glenarm, Mr. R. Lloyd Praeger, B.E., B.A., Mr. James Thompson, J.P., and Miss Sydney Thompson, of Macedon, Mr. W. A. Traill, C.E., and Mr. R. Welsh, on the Long Excursion; Colonel Bevington, at Sevenoaks.

Your thanks are also due to Sir Archibald Geikie, D.Sc., LL.D., F.R.S., Director General of H.M. Geological Survey, for the presentation of the necessary maps for the Long Excursion.

In consequence of the amount of work which falls upon your Excursion Secretary, your Council in January last appointed a committee of six to assist him in the organisation of the excur-sions for the coming season. Rules for the working of this com-mittee have been approved by the Council, and it is now recom-mended that this committee be re-appointed as soon as the new Council meets. Under the new scheme for the management of your excursions, your Excursion Secretary will be chairman of this committee, and will transact the official duties of the post, whilst the detailed arrangements and field work in connection with the various excursions will be distributed amongst the seven members of the committee, each member being entirely respon-sible for those excursions allotted to him. Since some division of labour has become absolutely necessary, your Council relies, with confidence, upon your rendering to the various members of the Excursion Committee in the field the same support which you have hitherto so unhesitatingly given to your Excursion Secretary; indeed, the success of this scheme depends upon that.

The committee appointed in January last was as follows: H. W. Monckton (chairman), H. A. Allen, R. S. Herries, T. Leighton, E. P. Ridley, W. P. D. Stebbing, A. C. Young.

Your thanks are due to the Council of University College for the facilities they continue to offer to the Association, facilities which are greatly increased by the courtesy of Mr. Horsburgh, the Secretary to the College.

The changes in our House List are considerable. General McMahon retires from your Presidency. You are indebted to him for that valuable and interesting paper on the Geology of the Himalayas, in which he explained in a concise and lucid manner the intricacies of Indian geology. He has paid the very closest attention to your interests on the Council, and those who have had the pleasure to be associated with him will readily acknowledge the admirable way in which he has dealt with several important and difficult arrangements. As punctual in the field as in the meeting-room, your thanks are doubly due to your retiring President.

Miss Raisin and Mr. H. B. Woodward retire from the list of Vice-Presidents, and Mr. French, Mr. Gibbs, Mr. H. B. Woodward, and Mr. Smith Woodward retire from the Council. Your thanks are due to all these. Mr. Thomas Leighton retires from the post of Excursion Secretary. It is difficult for the Council to adequately express their sense of the services rendered to the Association by Mr. Leighton. He has raised the Excursions to a level never before attained, and has kept them, as they should be kept, the first thing for which the Association exists. The Council feel that in suggesting Mr. Leighton's name as one of the new Vice-Presidents they will only be echoing the voice of the Members in their desire to mark their sense of the important services of our friend.

Finally, your Council submits the name of Dr. Charles Brongniart, the distinguished worker in fossil insects, and a member of the staff of the Paris Museum, as an Honorary Member.

The names of those suggested by your Council to fill the vacant offices will be found on the ballot paper.

On the motion of Capt. Stiffe, seconded by Mr. Richard Holland, the Report was adopted as the Annual Report of the Association.

The scrutineers reported that the following were duly elected as Officers and Council for the ensuing year:—

President:

E. T. Newton, F.R.S.

Vice-Presidents:

G. J. Hinde, Ph.D., F.G.S.	Thomas Leighton, F.G.S.
T. V. Holmes, F.G.S.	Lieut.-Gen. C. A. McMahon, F.G.S.

TREASURER:
R. S. Herries, F.G.S.

SECRETARY:
C. Davies Sherborn, F.G.S.

EXCURSION SECRETARY:
Horace W. Monckton, F.L.S., F.G.S.

EDITOR:
A. Morley Davies, F.G.S.

LIBRARIAN:
Wheatley J. Atkinson, F.G.S.

OTHER MEMBERS OF COUNCIL:

H. A. Allen, F.G.S.
H. W. Burrows, A.R.I.B.A.
Henry Fleck.
J. D. Hardy, F.R.M.S.
John Hopkinson, F.L.S, F.G.S.
Prof. Raphael Meldola, F.R.S.
George Potter, F.R.M.S.
Miss Raisin, B.Sc.
F. W. Rudler, F.G.S.
W. W. Watts, M.A., F.G.S.
B. B. Woodward, F.G.S., F.R.M.S.
A. C. Young.

On the motion of Mr. A. E. SALTER, seconded by Dr. W. FRASER HUME, the thanks of the Association were unanimously voted to the officers and members of Council retiring from office, to the auditors, and to the scrutineers.

The President then delivered his annual address, entitled "Some Structural Characteristics of the Granite of the N.W. Himalayas."

On the motion of Mr. H. B. WOODWARD, seconded by Mr. W. W. WATTS, it was unanimously resolved that the President's address be printed in full.

This terminated the Annual Meeting.

ORDINARY MEETING.

FRIDAY, FEBRUARY 7TH, 1896.

E. T. NEWTON, F.R.S., President, in the chair.

The donations to the Library, since the last meeting, were read, and thanks were accorded to the several donors.

There being no paper, the proceedings then terminated.

ORDINARY MEETING.

FRIDAY, MARCH 6TH, 1896.

E. T. NEWTON, F.R.S., President, in the chair.

John Dixon, M.D., and G. Denton were elected members of the Association.

The donations to the Library, since the last meeting, were read, and thanks were accorded to the several donors.

Mr. A. E. SALTER, B.Sc., read a paper, entitled "Pebbly Gravel from Goring Gap to the Norfolk Coast," which was illustrated by maps and specimens.

Mr. FREDERICK CHAPMAN, F.R.M.S., read a paper on "Some Pleistocene Ostracoda from Fulham," which was illustrated by diagrams and specimens.

Exhibits were made by Messrs. LEIGHTON, NEWTON, and DIBLEY.

ORDINARY MEETING.

FRIDAY, APRIL 10TH, 1896.

E. T. NEWTON, F.R.S., President, in the chair.

Lieut. C. G. Woodhouse, G. W. Pigott, and H. C. Coventry were elected members of the Association.

The donations to the Library, since the last meeting, were read, and thanks were accorded to the several donors.

Mr. WINTOUR F. GWINNELL, F.G.S., on behalf of Mr. HENRY PRESTON, F.G.S., and himself, gave an exhibition of lantern slides made from photographs taken during the two excursions to Ireland, the N. Wales, and the Isle of Wight excursions.

Exhibits were made by Messrs. SALTER, GWINNELL, MONCKTON, and NEWTON, and the President called attention to the rediscovery, during the recent visit of the Association to Purbeck, of the Chara-bed, recorded by Edward Forbes about 1859.

ON THE LAKE BASINS OF LAKELAND.

By J. E. MARR, M.A., F.R.S., Sec.G.S.

(Read 3rd January, 1896.)

TWENTY years have gone by since the late Mr. Clifton Ward published his observations on the depths of the lakes of Cumberland and Westmorland, and his views on the origin of those lakes * ; the knowledge of the physical features of the lakes obtained by Ward and by earlier observers did not appear to be adverse to the acceptance of the glacial erosion theory of lake-basins; and Ward himself, in the papers referred to, argued strongly in favour of that theory. In the absence of fresh information, many geologists have accepted this theory as far as the lakes of Cumbria are concerned. Recently, however, a most important contribution has been made by Dr. H. R. Mill to our knowledge of the physical features of these lakes,† under the title of "Bathymetrical Survey of the English Lakes," and it is desirable to see how far the new information at our disposal tells for or against the ice-erosion theory. Dr. Mill remarks that "the object of our survey was to lay down on maps the isobaths or contour-lines of depth, and so to compare the scenery of the subaqueous with that of the sub-aërial region of the Lake District"; and modestly adds: "I fear that this comparison, however completely it may be made, cannot throw much light on the origin of the lake-basins, for the original hollow, whether it were the result of cracking, or crumpling, or scooping, must be by this time effectually covered by the blankets of ever-thickening sediment, through which no distinct evidence of primitive form can be felt." It is the object of the present writer to show that Dr. Mill's work does afford considerable information concerning the origin of the lake-hollows, and the information is all the more valuable, inasmuch as it was collected without any desire to support or overthrow any particular theory.

It is generally admitted that the hollows in which lakes of the type we are considering lie can only have been formed in two ways; either (1) by erosion of the hollow beneath the surface of the water by some agent other than water, presumably ice; or (2) by the formation of a dam across the valley, which dam may be produced (*a*) by earth-movement; or (*b*) by accumulation of loose material, such as landslip-detritus, screes, rubbish falling down snow-slopes, or glacial deposit, sub-aërial or marine. If formed by erosion, through the operation of some agent other than water, there should be marked differences between the

* *Quart. Journ. Geol. Soc.*, vol. xxx, p. 96; and vol. xxxi, p. 152.
† *Geographical Journal*, vol. vi, pp. 46, 135.

scenery of the subaqueous and that of the sub-aërial region, whilst, if the lake-hollows have been formed by the formation of a dam across the valley, the subaqueous scenery may be expected to resemble that above the water-level. Dr. Mill's detailed work is eminently adapted to give us information upon this point, and I propose at the outset to consider it. There is, unfortunately, great difference of opinion as to the exact nature of the erosion which land-ice is capable of performing, and if anyone goes so far as to assert that the effects of ice are practically similar to those of running water, it would be difficult to bring forward convincing evidence as to the manner in which the lake-hollows were produced. There is, however, one structure which everyone will admit to be characteristic of ice, viz., the roche moutonnée, and I hope to prove that the nature of the roches moutonnées of Lakeland supplies us with a valuable argument. In discussing the various details of subaqueous scenery, we may conveniently consider the subject under the following heads: Submerged river-valleys, subaqueous alluvial flats, subaqueous cliffs, and roches moutonnées near water-level.

(1.) *Submerged River-Valleys.*—There are two ways in which the evidence of a submerged river-valley may be detected—firstly, by observing the nature of the lake-shore where a tributary valley joins the lake; and, secondly, by noticing the trend of subaqueous contour-lines. With reference to the first of these, if a lake-basin be eroded by ice the erosion may or may not occur also along the lower part of the course of a tributary valley, thus giving rise to a bay, whereas if the lake be formed by damming a valley of aqueous erosion, the entrance of an important lateral valley of considerable depth ought to be marked by a bay. I believe that it has been stated that such bays do not, as a general rule, exist, and, indeed, they are now rare, as the bay is usually filled up by detritus brought down by the tributary stream and converted into a delta with a convex curve; but in such cases the original concave curve may usually be seen, as, for instance (to take marked cases), the alluvial flat extending up the Newlands Valley, which must once have formed a bay a mile in length, opening into the old lake which has now been separated by alluvium into Derwentwater and Bassenthwaite, also the alluvial flat of Netherbeck in Wastwater, that of Sandwick and Castlehowe Point in Ullswater, and of Troutbeck in Windermere, and others less prominently shown. Other bays have not been completely filled by alluvium, as, for instance, Pullwyke in Windermere, and Howtown Bay in Ullswater, and here the streams entering the bays are comparatively insignificant, and the deltas, though in process of formation, have not advanced very far.

The accumulation of débris on the floors of the lakes will tend to obliterate sinuosities of contour due to submerged river-valleys, if such once existed; but any single case of the existence

of such a river-valley will be sufficient to dispose of the ice-erosion theory of the formation of the lake in which it occurs. Now, Dr. Mill's observations furnish some very remarkable cases of sinuosities of contour, which it is extremely hard to explain on this theory. In Windermere he notices "a channel about 100 yards wide, which, commencing off Ferry Head, runs close to the west shore, and spreads out to nearly the full width of the lake at Storrs Point. This channel suggests the remnant of an old river-valley by its narrow and sinuous course." That it is difficult to explain as the result of ice-erosion will, I think, be admitted by anyone who examines Dr. Mill's map of Windermere; but I shall eventually give reasons for supposing that, although it is probably a remnant of an old river-valley, it has since been largely covered up by débris, and that the depression is due either to the ncomplete filling of an old gorge by detritus, or owing to the greater shrinkage of the thick mass filling such an old gorge, than of the thinner deposits on the neighbouring shallows.* The sinuosities of contour lines pointing to the subaqueous prolongation of tributary valleys are still more difficult to explain on the ice-erosion theory, and are in accordance with what must occur if old river-valleys have been dammed up. An interesting case occurs at Howtown, at the top of the lower reach of Ullswater, where the short Fusedale Valley is continued down the lake, as shown by the apices of the V's of the contour lines including and above that of 100 feet, pointing up Fusedale.

In the case of Windermere, Dr. Mill observes that "two instances occur in which the isobaths down to 150 feet indicate branches or sublacustrine valleys running into the main depression. One of these is a deep channel passing through Pullwyke in line with the valley of the present stream, a remarkable instance of sedimentation not having yet effaced primitive structure. . . . The other instance occurs on the east coast, south of Ecclerigg Crag, where there is a sharp inflection of the isobaths, towards the north side of the square bay, which is bounded on the south by the Troutbeck delta. A similar, though less pronounced, inflection of the shallower isobaths is shown in the bay south of the Troutbeck delta, and it is possible that these may be indications of the primitive outline of the basin when Troutbeck entered a wide bay which it has now filled up, and the inflections represent the angles between the pyramid of river-borne detritus and the original wall of the basin." A glance at Dr. Mill's map of Windermere will show the strong probability of the correctness of his surmise in the case of Troutbeck. Pullwyke deserves fuller notice. The bay runs for half a mile westward, or at right angles to the axis of the upper part of the lake, and once extended twice as far, as shown by the alluvial flat extending up Pull Beck valley, of which valley the depression in Pullwyke is the subaqueous

* For similar instances above water see Marr, *Quart. Journ. Geol. Soc.*, vol l, p. 35.

prolongation. The beck has a short course, rising in an insignificant ridge which lies about two miles west of the lake, so that we can hardly suppose that this ridge formed gathering ground for a glacier which could scoop out the subaqueous depression in Pullwyke Bay. This depression, moreover, lies *at right angles* to the general direction of the ice coming from the fells north of Windermere, and we are driven to conclude that if the basin of Windermere was scooped out by ice, *it hollowed out a valley running at right angles to the direction of its course, and directly continuous with a pre-existing valley lying immediately to the west of it!*

The three furrows running down Derwentwater are probably, as Dr. Mill suggests, due to the occurrence of eskers forming the intervening ridges. Such eskers occur in the neighbourhood, and the islands which lie on the ridges are composed of drift.

(2.) *Subaqueous Alluvial Flats.*—Three of the lakes sounded by Dr. Mill—Buttermere, Crummock, and Wastwater—are remarkable for their "flat-floored, trough-like form." Buttermere "forms a simple trough, with steeply-sloping walls, and a nearly flat floor." Its greatest depth, 94 feet, is less than one-sixth of a mile from the head, and here "is a nearly rectangular plain, measuring 400 yards by 300 yards, the undulations on which nowhere exceed 4 feet, and that not in abrupt steps, but as a nearly uniform slope from one end to the other, the gradient being about 1 in 300. Crummock is 144 feet deep, and of its floor "208 acres lie below 125 feet, forming a plain 1½ miles in length, the lowest part of which is only 19 feet deeper. . . . From this flat plain the sides rise steeply—in some places they would be almost unclimbable if in the air—on both sides." In the case of Wastwater the part below the isobath of 250 feet, forming a "plain one mile long, and almost a quarter of a mile wide, undulates into one gentle dip of eight feet to the deepest soundings of 258 feet, which occurred in several places. Wastwater deprived of water would present a singularly impressive appearance, with its steep wall of screes frowning above its long, level, central plain." Coniston also possesses a plain, though not so marked as in the case of the three lakes just noticed.

These plains can hardly be due to glacial erosion, and certainly suggest deposition, which may have occurred before or after the filling of the lake. If they are caused by sediment accumulating in the lake, it is difficult to see why similar plains are not present in all the lakes, and their appearance is most in accordance with that of alluvial flats, formed in portions of old valleys before they were converted into lakes, and covered up fairly uniformly with a thin covering of sediment, and, possibly, of glacial débris, filling up the original river channels which

meandered through them. The sudden change from steep slope to flatness, in the case of Crummock especially, is more suggestive of such an origin than of lake-deposit. (See Dr. Mill's longitudinal section through Crummock, showing abrupt change from the delta slope to the flat floor.)

(3.) *Subaqueous Cliffs.*—Cliffs of exceptional steepness are recorded by Dr. Mill in Crummock, Ennerdale, and Wastwater. In the case of Crummock, "at Hause Point, on the right, the cliff ran sheer down, 70 *feet being found* 8 *feet off the rock*" (the italics are mine), "and the whole slope averaged 1 in 1, or an angle of 45° ; while that on the opposite side was scarcely less, if we reckon from a depth of 25 feet instead of from the actual shore. Here, in a total breadth of 500 yards, there is a plain 300 yards wide, with no diversities of level exceeding 5 feet, and averaging 130 feet below the surface. The slope of the sides at these points is as steep as any of the precipitous mountain cliffs which surround the lakes." In the case of Ennerdale "we find that the subaqueous slopes are quite comparable with those of the free hillside for steepness." Dr. Mill took detailed sections of exceptional slopes in Ullswater, and gives a figure of them (*loc. cit.*, Fig. 17) in his paper. "Two sections were made from the rocky point opposite the delta" of Glenridding Beck. "These slopes are almost exactly 83° in the first 6 feet," measured outward from the shore, that is, *a sounding taken* 6 *feet out from the shore gives, in one case, a depth of* 44, *in the other a depth of* 48 *feet.* I do not know whether any advocate of glacial erosion will claim Ennerdale and Ullswater as "ice scratches," having almost vertical sides of 70 feet in one case, and nearly 50 feet in the other.

(4.) *Roches Moutonnées.* These rounded rocks are stated to give unerring indications of the direction of the ice when possessing a rounded, polished, and fluted appearance on one side, and a rough one on the other ; and in such cases it is agreed that the rough side owes its character to having escaped erosion. As these rounded rocks usually have a small base, it is evident that much material has not been removed, when they are rough on one side and ice-worn on the other. But this practically implies that there has been but little ice-erosion in nearly all the upland valleys of Lakeland where this type of rounded rock is traceable, not only down to the heads of the lakes, but also along the sides down to and below water level, and *even on the rocky islands.* This character is specially noticed by Dr. Mill, in the case of the islands of Ullswater. He says : "The rocky islets all bear clear marks of ice-action, being smooth and striated, with gently-rounded curves toward the south, where the ice markings remain more distinct under water than on the dry surface. The northern sides of the islands show rough, angular fractures, indicating the advance of ice from the south." I have observed the same

feature on the islands of Windermere, but it is particularly important in the case of Ullswater, as the rough side is that which is away from the prevailing winds, and the roughness has not therefore been occasioned by subsequent erosion of a once-glaciated rock-surface. Ward felt the difficulty presented by the Windermere islets to the advocates of the ice-erosion theory, and remarked that "it is not quite clear why the islands at the centre of Windermere should have been spared by denudation to divide the present lake into two basins, since, so far as I can learn, there is nothing in the superior hardness of the rocks at that spot to explain it. It is the case, however, that just in that neighbourhood the valley widens somewhat; and thus, perhaps, the ice was enabled to spread laterally; while we may reasonably suppose that the islands represent only the degraded stumps of rocky hills which stood well above the valley-bottom in pre-glacial times." Difficult as the case of Windermere is to explain on the ice-erosion theory, that of Ullswater is still greater. House Holm, for instance, has a depth of 150 feet within about $\frac{1}{8}$ mile of its south-western end, and a depth of 175 feet in the same distance from its north-eastern end. In other words, if the ice eroded the basin of Ullswater, it must have removed at least 150 feet of rock in one place, practically none an eighth of a mile lower down, and 175 feet an eighth of a mile still lower down, although there is no important change in the character of the valley to account for the difference. If students of the physics of ice-motion assure us that this is possible, I, for one, shall be greatly surprised!

These islands are readily explicable on the supposition that the lakes occupy river-valleys which have been dammed. If we dammed up the higher part of Borrowdale, Castle Crag would form an island in the middle of the valley, and, as Mill points out, if Ullswater were 100 feet higher, Hallin Fell would stand out as an island a mile in diameter.

To sum up this part of our inquiry: The subaqueous scenery of the lakes presents several difficulties, on the supposition that they were formed by ice-erosion. Each of these difficulties may not be absolutely fatal to the theory in itself, but taken together they seem to me to furnish a mass of evidence which cannot be got over. On the contrary, the scenery can be readily accounted for on the supposition that the lakes are due to the damming up of river-eroded valleys, which have had a certain amount of material deposited upon their floors both before and after the process of conversion into lakes, and no single observation which has been made by Dr. Mill, so far as I am aware, is antagonistic to this view; indeed, they all harmonise perfectly with it. If we exclude the theory that the lake-basins were produced by ice-erosion, we are driven to adopt that of the blocking of river-valleys by solid rock or detritus, and to discuss the likelihood of

the Lakeland basins being due to a barrier produced by one or the other kind of material. I may here state that I commenced the study of the dams and lakes of Lakeland in hopes of showing that the lakes were due to the existence of rocky barriers, due to differential earth-movement, and was reluctantly compelled to give up this view after more detailed study. Unfortunately, the absence of deep borings deprives us of any direct evidence as to the nature of the barrier, but I have gathered together a considerable amount of indirect evidence which will, I think, render it more probable that the lakes are held up by superficial accumulations rather than by solid rock. I am aware that the difficulties in the way of this explanation were, twenty years ago, supposed to be very great. Clifton Ward, for instance, speaking of Wastwater, says that the presence of a moraine "does not explain the formation of the deep rock-basin, unless we could suppose that this groove, 40 feet beneath the sea-level, ran right on to the sea-coast, and was now wholly filled up with drift, with the exception of the present site of Wastwater, the drift deposit being more than 250 feet thick near the lake-foot—altogether a supposition highly improbable. Hence I think we may conclude that this lake is not *due* to the presence of a terminal moraine."* Before giving special arguments as to the nature of the lake-barriers, I may comment upon the asserted improbability of the existence of deep valleys filled with drift for several miles of their courses. In the case of land-ice issuing from mountain regions to flatter land, we may expect the transportation to be greater in the mountain track than on the plain track, where the gradient is generally less, and the ice can expand laterally; consequently a greater deposition of drift in a valley traversing a plain than in one traversing a mountain region is very probable; and, indeed, there may be no deposition to speak of in parts of the mountain region, and much in the plain. Or a mountain area standing out from a shallow sea, may have its valleys kept free of drift, whilst the submarine extension of these valleys may become partially or entirely blocked with drift.

The deposition of more drift in one part of a valley than in another, causing small lakes in the case of mountain-tarns, has been discussed by me elsewhere, and the formation of lakes in the same way is only a question of degree. Now, what evidence is there of the formation of great masses of drift by ice? As regards thickness, one of the best cases is the stratified, probably submarine drift, now raised up to form the Chaix Hills, rising through the Malaspina Glacier of Alaska.† Russell states that these hills "are composed of stratified morainal material," and that "it is evident that the minimum thickness of the deposit cannot be less than 4,000 or 5,000 feet." In our own country

* *Quart. Journ. Geol. Soc.*, vol. xxxi, p. 159.
† I. Russell, U.S. *Geol. Survey*, 13th Annual Report, p 25]

we find that Scarborough is situated on a drift-filled valley, the base of which is not seen, but the drift rises to a height of 171 feet above high water near the Spa.* Whitaker describes a case of an old filled-up valley occurring below the present Cam Valley, at Newport. Here, "after boring to a depth of 340 feet, the work was abandoned without reaching the Chalk, the Drift in this case reaching to a depth of about 140 feet below the level of the sea, though the place is far inland."† One of the best instances of a drift-filled valley, however, occurs in the outskirts of the Lake District itself, and is recorded in the memoirs of the Geological Survey.‡ At Park House Mines, in the Furness District, situated about 75 feet above sea-level, one bore gave a depth of 306 feet of drift, another of 369 feet, and another of 537 feet before reaching the solid rock. We have here an indication of a buried valley at least 450 feet below sea-level. Now a depth of 76 fathoms is the greatest depth met with in this latitude between England and Ireland, though there are several indentations of the 20-fathom line here and southwards, indicating the seaward extension of partially-filled valleys.§ The Park-boring must have struck a valley filled with drift or marine deposits, or both, for many miles from the point at which it was struck in the boring. This valley is filled with drift to its head; had it extended towards the heart of the district, its upper part might have been filled with a lake rivalling in size and depth any of those actually met with. It would appear therefore that there is really no difficulty in supposing valleys filled with drift along a course of many miles, and to a depth of several hundred feet.

Judging from the behaviour of what Russell terms piedmont glaciers, of which the Malaspina glacier furnishes a good type, we might well expect the sea-floor lying west of Scotland, Western England, and Wales, to be thickly covered with drift deposits, which would account for the greater depths of depressions lying near the mountains than of those situated further away, though of course this might also be produced by differential movements.

Passing on now to consider special cases of lakes, it may be noted that I brought forward evidence to show that the Lake District tarns were produced by the formation of drift dams across valleys,|| and later ¶ that a sheet of water, Hayeswater, described by Mill as intermediate between a tarn and a valley lake, was due to the same cause. If it can be shown that the larger lakes present features analogous to those furnished by the tarns, this will be strong evidence of their origin in a similar manner.

* Phillips, J., *Geology of Yorkshire*, Part I, third edition, p. 124.
† Whitaker, W., *Brit. Assoc. Report*, 1889, p. 588.
‡ Aveline, W. T., Explan. Quarter-Sheet 91, N.W., p. 4.
§ See Map attached to Report of Committee to investigate the Marine Zoology of the Irish Sea; *Brit. Assoc. Report*, 1894, p. 318.
|| Marr, *loc. cit.*
¶ Marr, *Quart. Journ. Geol. Soc.*, vol. lii, p. 15.

Commencing with the smaller lakes, an alluvial flat which iay well conceal a drift-filled valley extends between Grasmere 208 feet above sea level) and Rydal (181 feet), and though there ; not a continuous stretch of alluvium between the latter lake nd Windermere (130 feet), a somewhat hasty inspection coninced me of the probability of a drift-filled valley* occurring etween these two lower lakes. Thirlmere, one of the valley ikes of intermediate size, had a depth of 96 feet near its head, nd of 93 feet near its foot. It was† 533 feet above sea-level, and rained into the St. John's Valley, but the stream flowing from : approached within a few score yards of the alluvial flat of ie Naddle Valley, the watershed on which the hamlet of maithwaite stands being only 120 feet above the former level of ie lake. The Naddle Valley is filled with drift and alluvium for long distance below Smaithwaite; indeed, the drift extends to s junction with the Derwent. The low watershed (apparently f drift) between these two valleys is remarkable, but is easily ccounted for on the supposition that the Thirlmere River riginally drained down the Naddle Valley, but when the latter ecame filled with drift, the lake was formed to the level of the ol, formerly separating the Thirlmere Valley from the Vale of t. John.

Taking the larger lakes in order, we may commence with the)erwentwater-Bassenthwaite pair, which are generally admitted to ave been once united. Derwentwater is elevated 245 feet above ea-level, and has a maximum depth of 72 feet, whilst the altitude f Bassenthwaite is 224 feet, and its greatest depth 70 feet. The resent river issues from the north end of Bassenthwaite, and fter flowing northwards for a short distance, turns sharply to the rest. About halt a mile south of the present exit, Dubwath Beck nters Peelwyke from the west; it is a mere runnel, rising in a rift col a few feet above the present alluvial flat, a short distance rest of Embleton Station. Beyond this drift col, another small tream, Tom Rudd Beck, flows towards Cockermouth, occupying drift-filled valley, mostly covered by alluvium. The drift col etween the two streams is obviously a recent product, whilst the alley itself (the Embleton Valley) is a wide and important valley, rhich must have been formed by a considerable body of water. t is difficult to explain the existence of the two valleys (the resent Derwent Valley and that of Embleton) diverging from the Bassenthwaite depression, except by supposing that the drainage f the Derwentwater-Bassenthwaite system once went through the Embleton Valley, and that when this was blocked by drift, the ike was formed up to the level of the present outlet, and the verflow carried off by the present Derwent. It seems probable

* For use of term "drift-filled valley" see Marr, *Quart. Journ. Geol. Soc.*, vol. li, . 35.

† I use the past tense, as this lake has been artificially altered by the Manchester Waterorks Company.

that some of the material for the barrier was supplied by the Scotch ice, and in this connection it is interesting to note that the Sale Fell minette boulders have been carried southwards.

The Buttermere-Crummock pair of lakes lie S.W. of those last mentioned. Buttermere is 331 feet above sea-level, and Crummock 321 feet, the greatest depth of the former lake being 94 feet, and of the latter 144 feet. The river Cocker flows over solid rock shortly after its exit from Crummock water, but talus and peat occur between High Wood (about one-third mile S.E. of the exit of the Cocker from the lake) and Lanthwaite Beck, which flows north through a probably drift-filled valley, now covered by alluvium, and joins the alluvial plain of the Cocker about a mile to the north, the watershed between the lake and Lanthwaite Beck being less than 200 feet above the lake-level.

Loweswater, 429 feet above sea level, discharges its surplus waters into Crummock by Park Beck. It is of interest as being the only lake in the district of any size which drains towards, and not away from, the head of the district. At the head of the lake a stream runs, which flows from a col about 100 feet above the lake level; another stream flows northward from this col to join the Marron River. The drainage of a stream flowing from Floutern Tarn through one of the many Mosedales is somewhat eccentric. It runs through Mosedale in a general northerly direction, and looks as though it should flow through Loweswater, instead of which, on reaching the depression in which Loweswater is situated, it runs off at an angle of 290° from its former course to flow into Crummock. The somewhat remarkable behaviour of this stream may be readily accounted for, if we suppose that it once flowed northward and north-westward through the Loweswater Valley to join the Marron River; and when the Loweswater Valley was blocked by drift to a height greater than that of the watershed separating the Loweswater Valley from that of Crummock, the drainage was switched off into the latter valley. I have not yet examined the col at the upper end of the Loweswater Valley, but hope to do so ere long, and feel convinced that it will be found to be a drift-covered col.

Ennerdale, 368 feet above sea level, has a maximum depth of 148 feet. The Ehen issues from it through an alluvial tract, and flows a little south of west towards Cleator Moor, where it turns abruptly south, and enters the sea at Sellafield. The drainage of the streams on the west side of the Lake District presents many apparent anomalies, which can be explained on the supposition that their courses have been diverted owing to the thick accumulations of drift spread over this western low ground. The Ehen probably entered the sea near St. Bees, at one time, and owing to the filling up of the valley over the plain by drift, that

part was directed southward, though it still flows over its original site for some miles below the end of the lake.

Wastwater is about 200 feet above sea level, and its greatest depth is 258 feet. Its deepest part is thus below sea level. Two apparent anomalies in the drainage of the region are noticeable; Countess Beck appears to enter the lake about half a mile from the foot, and also to enter a river at the other end. I have not carefully examined this tract of recent years, but my recollection is that a drift-filled depression runs along the course of Countess Beck past a small tarn to join the Irt (the river issuing from Wastwater) near Kidbeck. Shortly below this the river Bleng, a tributary of the Irt, joins the main river, after a very remarkable course. For about six miles from its source the Bleng flows in a south-westerly direction to within a short distance of Gosforth; it then turns back almost parallel with itself, and so flows into the Irt, which presently turns south-west once more, so that the waters of the Bleng and the Irt below it flow in a sharp S. Near Gosforth the Bleng is about three miles from the sea, and separated from it by no very high ridge. The apparent anomalies can be readily explained if we suppose that the Wastwater Valley, once drained by Countess Beck, passed Gosforth to the sea, and was joined by the Bleng. The filling of the valley by drift would cause the filling of the Wastwater depression to the level of the present exit, and the diversion of the drainage of the Bleng at right angles to its former course.

Coniston is 143 feet above sea level, and has a maximum depth of 184 feet, so that portions of this lake also are below sea level. I have not examined the course of the lake which issues from its foot in recent years, but according to my recollection of it, it runs through a marshy valley with no rock-exposures until it falls into the Leven Estuary. In this case the lake may be simply due to the filling up of an ancient valley to a higher level (that of the present exit, or a few feet above it). The maximum of drift required would be about 200 feet.

Windermere has a surface 130 feet above sea level; its maximum depth is 219 feet. This lake, and the two just considered, are the only ones in the district the lowest parts of which are below present sea-level. The foot of the lake forms a sigmoidal bend, from which the River Leven flows through a rocky valley, flowing south-west to the estuary. The depression of the Windermere Valley is, however, continued due south to the Cartmel Valley, which is one of considerable importance, though drained by a mere runnel. The col between the lake and the Cartmel Valley is very little elevated above the level of the lake. I recently followed this valley past Cartmel to the sea, and found that it might well be drift-filled all the way from the foot of the lake to the sea. Many peat-mosses exist along this line,

indicating the former existence of a number of lakelets in drift-hollows.

Haweswater is 694 feet above sea-level, and has a maximum depth of 103 feet. As far as I recollect, drift occurs down the present valley, either along the course of the stream or near to it, until it joins the Lowther, and this river also shows no rock in its course for some distance below Bampton.

Ullswater is 476 feet above sea level, and has a maximum depth of 205 feet. The Eamont, which issues from its foot, flows, as far as I am aware, through a drift-filled valley, mainly overlain by alluvium, to its junction with the Eden.* The latter river flows through alluvial flats until it reaches the gorge commencing below Little Salkeld, where the first rock is seen in the bed of the stream, at a height of about 270 feet above sea level, or about 100 feet lower than the deepest part of Ullswater. This lake may well have been formed by the filling up of a river-valley with drift for some distance below the foot of the lake, in which case the present Eamont is flowing at a higher level along a course situated approximately above that of the pre-glacial stream. It is by no means certain, however, that the Eden ran through the Little Salkeld and Armathwaite gorge in pre-glacial times, and it is possible that it ran through a valley to the west of this, now largely filled with drift, though the existence of this western valley is not necessary for the formation of Ullswater by a drift barrier.

In the above portion of my paper it has, I believe, been shown that the filling of valleys by drift to a considerable depth, and for many miles of their course, is by no means improbable; that all the valley lakes of Lakeland are connected with valleys so filled with drift as to render it possible that these drifts form barriers sufficient to account for the existence of the lakes.† Until the existence of the drift to a sufficient depth to form the required dam is disproved, the existence of rock-basins in Lakeland cannot be unhesitatingly asserted by anyone.

Further than this, there are certain apparent anomalies in the distribution of the present drainage in the case of all the larger valley lakes, except Ennerdale, Coniston, Haweswater, and Ullswater, which are not actually incompatible with the theory of glacial erosion, nor with that of differential uplift, but which receive a more satisfactory explanation upon the view that they are due to blocking of valleys with drift. Again, the drift occurs in these valleys where it ought to be found, if the lakes were formed in this way; moreover, the apparent anomalies in the distribution of the drainage connected with the larger lakes are exactly comparable with those which occur in the case of the tarns,

* The old valley lies somewhat north of the present stream, near Edenhall.

† It will be seen from the text that I have not examined all the valleys below the lakes in detail, but have examined several carefully, and, all except that at the N.W. end of Loweswater, with some degree of care.

as to the formation of which by drift dams I have given evidence elsewhere. I can find no real distinction between tarns and valley-lakes, and a transitional series, such as Hayeswater, Devoke Water, Rydal, and Grasmere can be traced.

There is one difficulty in the way of this explanation of the lakes, the consideration of which I have reserved until now, namely, that many of the lakes are deepest near the head. Of the large lakes we find that this is the case with the following: The Derwentwater-Bassenthwaite Lake, Buttermere (though, if we treat Buttermere and Crummock as one, this is not the case, Crummock being deeper than Buttermere), Windermere, and Ullswater. Wastwater is deepest about the centre, Haweswater and Coniston near the centre, and Ennerdale alone nearer the foot. In the case of Windermere we require a dam sloping gently from the mouth to the present head. The difficulty appears greater than it really is, for the present head of most of the lakes is some distance below the original head, owing to the cutting down of the outlet, and the filling up of the head by alluvial material; thus Ullswater and Windermere probably extended very much higher up their valleys than they do now, whilst the deepest parts of the Derwentwater, Bassenthwaite, and Buttermere-Crummock areas may originally have been beneath the alluvial tracts which now separate the lakes, due to the large lateral valleys which enter the main valley opposite to them. The difficulty is further diminished, if it does not disappear, when we remember that much of the glacial drift which borders the Lake District was not derived from the centre of the district. The existence of boulders from the north on the north-west sides of the district, and also on the east side, in the Eden Valley, indicates that much of the material laid down on those comparatively flat tracts had a northern origin, and this material would block Ullswater and Haweswater on the east, Bassenthwaite and Crummock on the north, and Ennerdale and Wastwater on the west. Again, the drift in Morecambe Bay, coming from the north-east, would furnish material for stopping up the Windermere and Coniston valleys. This material would naturally be washed towards the centre of the district, and gradually thin away in that direction, in the form of "kettle-drift," enclosing hollows and sinuous channels like those found in Derwentwater, Windermere, and other lakes.

I had hoped at one time to be able to show that the lakes were due to the settling down of the central dome of the district, and the formation of barriers owing to the production of a ring of rock by a "creep" process, at points about equidistant from the centre of the district. The idea was a fascinating one, but the evidence I have gathered does not appear to be in favour of it. Earth-movements must have occurred, if the lake-basins were not hollowed by glacial erosion. The existence of tracts of lake-floor

below sea level in Windermere, Coniston, and Wastwater requires this, as also the great accumulation of drift at Park House Mines in the Furness District, but this movement appears to be one of widespread depression, as indicated by other evidence in the form of buried valleys, etc., elsewhere. As to the date of this depression we have not much evidence. It was probably pre-glacial, and may have been of Pliocene date, but the actual period of its occurrence does not much concern us in connection with our present inquiry. Nor is it of much importance whether the drift material which, according to my belief, formed the dams which ponded back the waters of our larger lakes, was accumulated by land ice or by floating ice, or by a combination of the two, though I have elsewhere given some of my reasons for adopting the views of those who are most competent to speak of the glaciation of the district, that it was largely the product of terrestrial glaciation. If the drift dams are there we yet await the evidence which will convince us that the lakes of Lakeland are held up by rocky barriers; and even should this prove to be the case, I feel convinced that the valuable detailed observations of Dr. Mill show that the rocky barriers were not produced by erosion in places higher up the valley, but by differential earth movements.

I should like to add in conclusion that geologists are deeply indebted to Dr. Mill for his painstaking work, and that I myself am very grateful to him for the interest he has taken in geological as well as in purely geographical questions connected with the water areas of Lakeland.

SOME STRUCTURAL CHARACTERISTICS OF THE GRANITE OF THE N.W. HIMALAYAS.

(Illustrated by Plates VIII, IX, and X, reproduced directly from Micro-Photographs.)

By LIEUT.-GENERAL C. A. McMAHON, V.P.G.S.

[*Being the Presidential Address delivered 7th February*, 1896.]

IN the address I had the honour to read last year on the geological history of the N.W. Himalayas, I briefly indicated the important part granite had played in that history, and I stated "that the contortion, compression, and upheaval which marked the earth movements that set in at the close of the Eocene period, were connected with the intrusion of the gneissose granite."

I purpose in this address to give you a short account of some of the salient characteristics of this granite, more especially those connected with its internal structure.

As the Himalayas cover an enormous area, and parts of them are, geologically speaking, still imperfectly known, I limit my remarks to the outcrops of the gneissose granite along the southern borders of the Himalayas.*

The intrusive character of this granite is now admitted.†

The evidence on which this determination rests may be briefly summarised as follows: *Firstly*, it produced metamorphism in the rocks in contact with it. *Secondly*, it sent out veins and tongues into these rocks. *Thirdly*, it appears in different geological horizons. *Fourthly*, it contains included fragments of slates and schists, wrenched off the rocks through which it passed. *Fifthly*, under the microscope it exhibits structures characteristic of an acid holocrystalline igneous rock.‡

It would not be possible to compress within the limits of a Presidential address a full and comprehensive description of the Himalayan granite. I must content myself, therefore, with stating briefly the conclusions I have arrived at regarding the history of the rock, and with giving you, by way of sample, some illustrations of the kind of evidence furnished by the microscope in support of these conclusions.

The granite was, I hold, in the first instance, more or less

* See Sketch Map, *Proc. Geol. Assoc.*, vol. xiv, p. 80.
† *Manl. Geol. of India*, 2nd Edn. Oldham, pp. 41—43.
‡ See Author's papers in *Records Geol. Survey India*, and a summary in *Geol. Mag.*, May, 1889, p. 212.

completely crystallised at plutonic depths under conditions of great heat and great pressure. This stage in the history of the rock, evidenced by the large porphyritic crystals of felspar which still remain in it, was followed by an upward movement when the relief of pressure consequent on the rise, aided possibly by the heat produced by the friction of the crystals contained in the granite against each other, caused a partial remelting of the rock;* and finally the granite was forced in thick sheets between beds of strata, and into the faults and fissures opened up in the course of the compression, uplifting, and contortion of the rocks, which set in within the Himalayan area at the close of the Eocene period.

The stresses and strains that accompanied this intrusion seem to have been severe. In some localities the intruded rock passes rapidly from a foliated to an unfoliated granite; but, as a general rule, it is more foliated along the margins, where it is in contact with sedimentary rocks, than at a distance from them; and, where the outcrop dwindles from a width of ten or eleven miles to a strip in the valley of the Ravi only 250 yards wide, the strain attained great intensity. The rocks, at this point, are bent in wide curves, as you might bend a green bough across your knee, and the gneissose granite passes at its edges into a rock that might, without microscopical examination, be taken for a mica schist.

This extreme schistose condition is confined to the axis of special strain above alluded to. At other places the contact of the granite and slates is of more ordinary character. Huge slabs of sedimentary rocks may be seen at the Chuhári pass in process of being surrounded by the intruding granite, and of being torn away from their parent beds; whilst the granite itself, there and elsewhere, contains numerous foreign fragments, which have been carried considerable distances. The granite at its junction with the slates is considerably foliated, and thin slices of it, under the microscope, exhibit strong fluxion structure.

Speaking generally, traction, and not shearing, is the main characteristic of the granite at its contact with the sedimentary rocks; but a comparatively narrow band of granite below Dalhousie appears to have been sheared as well as compressed.

Field evidence that the granite, at the time of its intrusion, was in a partially consolidated condition is not wanting. For instance, intruded tongues and veins are in some cases † strongly porphyritic, and large porphyritic felspar crystals, I need hardly observe, cannot have been formed *in situ after* these tongues and veins were intruded into the sedimentary rocks.

* In the case of most crystals the melting point appears to be raised by pressure, and lowered by relief of pressure.
† *Records Geol. Survey India*, vol. xv, 45.

If, then, the granite, at the time it was forced, under conditions of great lateral and upward pressure, between the jaws of faults, was in a semi-crystallised condition, one would naturally expect to find the signs of pressure, traction, and strain to be present when we examine slices of the rock under the microscope. Undulose extinction, fractured minerals, crumpled micas, and such like evidence of strain and mechanical action to be found in these rocks, do not, however, prove that these phenomena were produced by mechanical forces acting on a cooled and consolidated rock. No geologist of mark, nowadays, believes in mountains having been created by sudden convulsive movements that died out as rapidly as they set in. It seems only reasonable to suppose that the pressure and strain on the cooling granite continued more or less from the period of its intrusion until its complete consolidation. The forces that caused the folding and faulting of the strata must have been long sustained to have produced the effects now to be seen in the sedimentary series. As the cooling and consolidation of the granite gradually proceeded, therefore, this continued strain was exerted on a rock gradually progressing towards rigidity; and though, towards the close of the solidifying stage, individual minerals that had become rigid were crushed together and fractured, the granite itself only yielded locally to plastic deformation. The evidence I shall adduce shows that the fracturing of the minerals contained in the rock took place when it was approaching, but had not, as a whole, attained complete rigidity; and the fact that the granite passes locally from a nonfoliated to a foliated rock may be explained on the supposition that complete solidity was attained in some portions of the mass in advance of others; the former resisted, whilst the unsolidified portions yielded to the pressure, and were stamped with more or less parallelism of structure.

Several causes might be suggested which possibly contributed in different degrees to prevent the granite cooling down, and solidifying, at a uniform rate throughout its mass, but it would unduly lengthen this address to discuss them. I will only say in passing that the sedimentary cover above the granite probably varied considerably in thickness from place to place; the strata in contact with the intruder probably differed locally in their conductivity; the stresses must have varied in their severity from point to point; and later intrusions from the still liquid magma below may have brought fresh supplies of heat to special localities.

The evidence I am about to lay before you, I think, negatives the hypothesis that the foliation, and other characteristic structures of the granite, were produced by the shearing of a solid rock.

With this brief introduction I pass on to describe the granite more in detail.

The rock is always more or less porphyritic, and the porphyritic crystals, which attain a length of three inches, are generally

abundant. The ground mass is usually of medium sized grain, but in one locality it is of so fine a texture that it might, in the field, be mistaken for a felspar porphyry.

The mineralogical contents of thin slices* of the granite examined under the microscope may be presented in a tabular form as follows, the numbers given representing the number of slices in which the minerals specified occur:

Total Slices Examined.	Quartz.	Microcline.	Orthoclase.	Plagioclase.	Muscovite.	Biotite.	Schorl.	Garnet.	Magnetite.	Ferrite.	Zircon.	Sphene.	Augite.	Epidote.	Zoisite.
72	72	34	52	57	63	62	20	58	59	59	11	11	1	4	5

The plagioclase is either albite or oligoclase—some of it is certainly oligoclase, and probably most of it may be referred to this species.

Mr. J. Hort Player, F.G.S., F.C.S., has been kind enough to make analyses of four typical samples of the Dalhousie granite, for which I am greatly indebted to him, and which I give below. These are of great value, as no analysis of the granite† of the N.W. Himalayas has yet been published.

THE GNEISSOSE-GRANITE OF DALHOUSIE, N.W. HIMALAYAS.

	I.	II.	III.	IV.
Silica	71·8	71·9	73·5	74·9
Titanic Acid	—	tr.	tr.	—
Alumina	14·2	15·9	15·1	14·6
Ferric Oxide	2·1	·9	1·2	·7
Ferrous Oxide . . .	1·9	1·3	·7	·6
Lime	·5	1·3	1·1	·5
Magnesia	·9	·6	·3	·1
Soda	1·7	2·8	·9	2·6
Potash	5·3	3·6	6·1	4·8
Loss by ignition . . .	1·5	1·2	·9	·9
Total . . .	99·9	99·5	99·8	99·7
Specific Gravity‡ . .	2·620	2·708	2·625	2·619

I. Outer band Dhalog Ridge. II. Upper Bakrota. III. On the road to Chil. IV. Top of Dainkund.

* A considerable number of fresh slices have been made for the purpose of this address.

† Mr. Mallet gave an analysis of the felspar in the granite of Wangtu in the interior of the Himalayas (*Records Geol. Survey India*, xiv, 238), but not of the granite itself. Moreover, the latter probably belongs to a somewhat different period to that now described.

‡ The Sp. G. of II and III was determined by Mr. Player; I and IV by the Author.

Thin slices cut from the specimens which furnished material for the chemical analyses contain the following minerals:

No. of Analysis.	Quartz	Orthoclase.	Microcline.	Acid Plagioclase.	Muscovite.	Biotite.	Schorl.	Garnet.	Magnetite.	Ferrite.	Zircon.
I.	+	+	+	—	—	+	—	+	—	+	+
II.	+	+	+	+	+	+	—	+	+	+	+
III.	+	—	+	+	+	+	+	+	+	—	—
IV.	+	+	—	+	+	+	+	—	+	—	—
4	4	3	3	3	3	4	2	3	3	2	2

The quartz in the granite under description appears to belong to two stages of consolidation; the quartz of the earlier stage consisting of large allotriomorphic grains. The quartz of second consolidation represents in part the uncrystallised residue left after the first partial consolidation of the rock; and in part, the quartz which was remelted during the upward movement of the granite towards the surface.

The quartz of the second epoch was the last mineral to crystallise at the final consolidation of the granite. It exhibits a micro-mosaic structure, the micro-grains being generally without crystallographic shape, but at other times, where the final solidification presumably took place at localities comparatively free from strain, the micro-grains exhibit distinct polygonal and hexagonal outlines.

The quartz of the second epoch which I shall in future, for the sake of brevity, term the tessellated quartz, exercised, whilst in a fluid condition, a distinctly corroding and solvent action on most of the other minerals. It also invaded orthoclase, microcline, plagioclase, mica, and schorl, very much in the way the field geologist is accustomed to see granite invade and pierce sedimentary strata. Instance, Fig. 1, Plate VIII.

Under the microscope—and this point can be made out in the photograph with the aid of a lens—the micro-dykes of quartz are seen to have exercised a corrosive action on the orthoclase, the line of junction between the two being distinctly serrated. Infiltrated quartz filling cracks, which the petrologist sees in some rocks, presents a very different appearance.

Fig. 2 is another illustration of tessellated quartz corroding the edges and cutting boldly across a crystal of microcline

Fig. 3 represents a similar case. Here, too, it will be observed that the quartz has not only penetrated cracks but has corroded and eaten into the felspar at the sides and top.

In the preceding pages I have described how blocks of slates have been torn off sedimentary strata and floated away in the

rising granite. Something of the same kind of thing may be seen under the microscope. Fig. 4 supplies an instance of aggression committed by the tessellated quartz on the helpless orthoclase. To the left may be seen at (*a*) a piece of felspar that has already been detached and floated off from its parent crystal; whilst at (*b*) another is depicted, which, had the process not been arrested by the consolidation of the rock, would soon have followed its brother.

An important point to determine in connection with the history of the Himalayan granite is the origin of the tessellated structure of the quartz. A close study of my thin slices has led me to the conviction that this structure has not been the result of the shearing, crushing, or grinding of these rocks *after the crystallisation of the quartz.* Figs. 1, 2, and 3 show, I think, conclusively that the rock was not sheared or ground down between the injection of the felspars with quartz and the solidification of the latter mineral; had it been, the broken fragments of felspar would have been separated from each other, drawn out, and ground down into rounded grains. Figs. 1, 2, and 3, I think, show this sufficiently. Fig. 5 supplies another example, of which numerous instances could be given.

The schorl represented in this illustration is cracked through and through in all directions; one of the cracks, that on the right hand towards the bottom, is so fine that a lens is required to make it out in the photograph. Here the quartz has quietly welled up into the cracks, and at the time this took place no shearing could have been going on, and there could have been very little, if any, movement in the part of the mass from which the hand specimen was taken. Numerous other equally striking examples in illustration of this point could be taken from hand specimens derived from other localities. I shall content myself with one more.

The tessellated quartz (see Fig. 6) has in this case penetrated between two transverse cracks in the schorl crystal, and forced the pieces apart; but the displacement of the pieces only amounts to ·010 to ·015 of an inch. The felspar (*e*, *f*, *g*), it will be seen, has been divided into four pieces, and penetrated by the quartz at *f* and *g*.

These and other instances which abound in my slices not only prove, as just stated, that the tessellated structure is not due to shearing, or grinding, whilst the injected quartz was still plastic, but also demonstrate that it was not due to such action after the solidification of the injected quartz. The grinding down of the quartz that cements the pieces of fractured minerals together, into grains of microscopic size, without disrupting and scattering the fragments of those minerals, seems to me, if not a physical impossibility, to be at all events a very delicate operation, that would greatly tax even the ingenuity of nature.

Other facts afford confirmation of the view that the granite had come to rest, and that very little internal motion took place after the crystals now visible in it were cracked and fractured by the compression of the granite between the walls of the fissures through which it was intruded. The felspars, particularly along the margins of the intruded mass, are often much fractured, but the displacement of the broken pieces was, as we have seen, very trifling. The felspars are often faulted, but the throw of the microscopic faults is very small, and to be measured by the thousandths of an inch.

That the pressure that caused the injection of the quartz into the fractured felspars was posterior to the strain that caused the cracks is a self-evident proposition; and that it was also posterior to the strain that impressed strain shadows on the quartz of first consolidation is also clear, for I have observed numerous instances in which the tessellated quartz cuts right through quartzes of first consolidation without in any way disturbing the orientation of these shadows.

If the tessellated structure of the quartz of second consolidation was not caused by shearing or grinding *after* the quartz was injected into the cracked and fractured minerals, the further question arises, was it produced by grinding or shearing *before* the quartz was forced into the cracks it now fills? In other words, was the quartz forced into the cracks in the condition of fine sand, or did it penetrate the cracks in a liquid or plastic state?

I do not consider that the sand hypothesis will bear investigation. Not to mention the powerfully corrosive action exercised by the tessellated quartz on the other minerals, think of the amount of grinding required to triturate at least half the quartz contained in a granite the outcrops of which extend for hundreds of miles, and are from ten to fifteen miles in width, to reduce it to grains as small as one one-thousandth of a inch! Anyone who has exercised his fingers grinding quartz down with an agate pestle and mortar will have a lively appreciation of the magnitude of the task. Nature, it is true, has a big laboratory and works on a large scale; but if, in the Himalayan workshop, half the quartz in the granite was ground down to grains as small as one one-thousandth of an inch, is it conceivable that all the felspars in the rock should have escaped? Not to mention the crystals seen in the slides, the granite abounds in large porphyritic crystals of felspar of first consolidation which frequently attain a length of three inches, and generally present fairly good crystallographic shapes. If powerful grinding action had been going on to the extent postulated, is it possible to conceive that these crystals could have escaped that action?

The tessellated quartz in the granite is not confined to the margins of its outcrop, or to the foliated portions of it, but

occurs all through the rock and is a striking characteristic of the whole of it.

Tessellated structure in quartz, I may mention in concluding my remarks on this portion of my subject, is not necessarily connected with mechanical action of the nature of shearing or grinding. It is not unfrequently the result of strain at the moment of crystallisation, and the requisite strains may be produced in a variety of ways other than by shearing or grinding. Strains may be set up by simple pressure; namely, by the compression of strata, or by the expansion of neighbouring minerals in passing into the crystalline condition.* Strains may also be produced by unequal heating or cooling. In *The Mineralogical Magazine*, vol. viii, p. 10, I gave a striking illustration of an idiomorphic, undeformed, phenocryst of quartz found in a quartz-porphyry, which displays the tessellated structure perfectly. I have come across other instances in modern lavas.

The explanation which I have to offer to account for the tessellated structure of the quartz in the Himalayan granite is briefly as follows: I have already suggested that the granite was more or less crystallised before it was moved from the plutonic depths in which the large porphyritic crystals of felspar were formed: that a partial remelting took place during the upward movement; that the granite was forced through fissures and faults, and between beds of stratified rocks, in a semi-crystallised condition; that the earth movements connected with this eruption did not at once die out; and that the compression of the granite lasted from the time of its intrusion down to, and possibly for some time after, its gradual and final solidification. The quartz of second consolidation was the *last* mineral to crystallise; and the view I hold is that the strain caused by compression at the moment the free silica crystallised, caused it to crystallise in micro-granules instead of in large crystals. The formation of large crystals in igneous rocks seems to require time for their gradual growth, and sufficient heat to permit freedom of molecular motion; hence one so often sees in igneous dykes coarseness of grain in the centre, and fineness of grain (or a glassy condition in rocks consolidated at the surface) along the margins which presumably lost heat more rapidly than the centres of the dykes.

The crystallisation of the quartz of second consolidation—the last mineral to solidify—was probably rapid. To this day earthquakes are very common along the outer Himalayas; and at the period under consideration the uncooled granitic magma below the consolidated granite may have sent up constant tremors to the crust above it; in which case these vibrations may have

* Ice supplies a good illustration of the class of minerals that expand on passing into the crystalline condition.

supplied the molecular impetus required to induce rapid crystallisation.*

I must now pass on to describe briefly another very striking characteristic of the granite; namely the presence of what, for the sake of brevity, I termed in my former paper crypto-crystalline mica. This is a true mica—generally muscovite but sometimes biotite—the leaves of which are so minute in size, and are felted together in such a heterogeneous manner that when low powers are used the mass has the appearance, under the microscope, of an amorphous substance. With high powers the real nature of the crypto-crystalline mica can be made out. Occasionally it passes into a micro-crystalline condition in which the individual crystals can be seen with low powers.

The colourless, or light coloured, crypto-crystalline mica possesses the optical properties of muscovite, and it is not affected by long continued heating in hydrochloric or nitric acids.

The crypto-crystalline mica is present in forty-six out of fifty-five thin slices of the Dalhousie granite; and in two out of thirteen samples of the Chor granite; but it does not occur in slices cut from five specimens from Hattu and Bági in the neighbourhood of Simla.

In thin slices under the microscope the crypto-crystalline mica is seen floating about in sinuous streams in the way shown in Fig. 7.

These streams in their serpentine course afford striking illustrations of fluxion structure. They are not, however, confined to the tessellated quartz, but traverse crystals of felspar, particularly the large ones, in a way that suggests, at first sight, the idea that the crypto-crystalline mica is due to aqueous agents acting on the felspar through cracks. A careful study of the numerous specimens examined, however, has satisfied me that this is not the case. The colourless crypto-crystalline mica is intimately connected with large leaves of muscovite, and the dark crypto-crystalline mica is directly connected with leaves of biotite. They never blend together and only occasionally become entangled with each other.

I can see no grounds for supposing that the crypto-crystalline mica is due to the mechanical grinding down of the large micas of first consolidation. The crypto-crystalline mica is not confined to the marginal portions of the granite in contact with slates; it is a striking characteristic of the whole granite, and occurs in the unfoliated as well as in the foliated portions; thus it is present in all my specimens from the top of Dainkund, two miles away, as the crow flies, from the nearest junction of the granite with the slates, the structure of the granite there being perfectly granitic and

* See the effect of "mechanical disturbance, such as shaking" in bringing about the solidification of a supersaturated solution, *Outlines of Theoretical Chemistry*, by Lothar Meyer, English Translation, p. 132.

unfoliated. It also occurs as a contact metamorphic product in the slates in contact with the granite, and in the fragments of schists included in the granite, as for example in that shown in the plate at p. 174 *Records Geol. Survey India*, vol. xvii. This inclusion has not been sheared, and the crypto-crystalline muscovite in it cannot therefore be a product of shearing or grinding.

Such cases as those shown in Figs. 8 and 9 suggest to my mind the flow of a viscid mass encumbered with numerous solid crystals.

Fig. 8 (taken from the margin of the granite in contact with the slates) shows, I think, that if the pressure and grinding had been sufficient to break up slippery plates of muscovite into crypto-crystalline mica the crystal of felspar therein represented could not have boldly stood up in a contumacious manner against the pressure brought to bear on it. It would have been ground down, like the mica, to a fine grained paste.

Fig. 9 is taken from the margin of the comparatively narrow outer band of granite below Dalhousie, which has undoubtedly been subjected to very great lateral compression, and also to shearing in the direction of the thrust of the sheet intruded between the strata. I have given this illustration because it represents an extreme case, and it is one that some may think, at the first blush, tells against my views. The photograph certainly shows that the nip was severe; but I see no reason to jump to the conclusion that the dark crypto-crystalline mica seen in the illustration owed its origin directly to a mechanical shear. If it did, I would ask again why were the felspars not ground down? They were not slippery gentlemen like the biotites and muscovites, and could not have wriggled themselves away from the force of the grind and shear.

The view I have formed on a study of all my specimens is that the crypto-crystalline mica is due to the *melting*, or re-solution, of muscovite and biotite. It is a phase of the partial re-solution, or remelting, of the granite which appears to have affected almost every mineral in the rock. On this hypothesis one can readily understand how the dissolved mica penetrated into large felspar crystals along cracks, solution-planes, and other lines of weakness, and how it was carried into the included fragments of foreign rocks, as well as into the slates in contact with the granite.

Mica under ordinary conditions at the earth's surface resists heat well, but not entirely, for it fuses at the edges under the blowpipe. In the granite it was under conditions of great heat and great pressure, and was moreover in contact with superheated water and fluxes. That it yielded to their powerful influence is abundantly evident from a study of my thin slices. Fig. 10 shows a large muscovite corroded all round its edges and nearly cut in two by an intrusive vein of tessellated quartz. Many

other striking illustrations could be given to prove how vulnerable the mica was to the inroads of quartz.

Fig. 11 shows us three muscovites (*a*, *b*, *c*)—originally, in all probability, one large one—in process, apparently, of being melted down into crypto-crystalline mica, which is seen flowing all round it. At (*d*) another muscovite is seen, which is corroded and frayed out into ragged edges at the top, bottom, and left side.

The way (*a*) and (*b*) are being split up reminds one of the way leaves of mica so often separate from each other and curl under the blow-pipe. These micas do not suggest to my mind the idea that they were being ground down by mechanical friction, but rather that they were breaking up under the action of a heated solvent.

Fig. 12 represents a large biotite in the first stages of decay. The iron has segregated into grains which, when the photograph is examined with the aid of a lens, gives it a blotchy appearance; and the biotite has changed colour from black to reddish brown. It is deeply corroded at (*a*), (*b*), (*c*), and (*d*), and melted portions are floating away in one direction at (*e*) and (*f*), and in another direction at (*g*).

Fig. 13 represents another interesting case, in which the melting process has been carried a stage farther. The biotite has lost all trace of shape, cleavage, and structure, and has become a mere collection of micro-leaves, which, under the influence of traction, were floating off at both ends of the nebulous-looking patch when the rock solidified.

The curved stripe below the biotite is crypto-crystalline muscovite. It will be observed that the strings of biotite and muscovite do not present rigidly parallel lines, but exhibit the wavy, undulating curves characteristic of such light material as minute leaves of mica floating in a viscid medium in a state of flux.

Another interesting fact about the crypto-crystalline muscovite is that it exercised a corroding influence on felspars. Fig. 14 gives a case in point. The stream of crypto-crystalline mica (*a*) (*b*) has eaten deeply into a crystal of orthoclase at (*c*). The dark spot to the left produces the impression that the felspar is faulted, and that the upper half of the crystal overlaps the lower. That is not so. The dark spot is a hole worn in the felspar when the slice was being ground down for the microscope. Between crossed nicols this comes out dark. Under the microscope this hole is seen to be well within the boundary of the crystal, which is fairly symmetrical, except where eaten into by the crypto-crystalline mica above and the tessellated quartz below.

The dark line seen in the illustration is not, as might be supposed from the photograph, a line of shear. It is simply a string of crypto-crystalline biotite entangled with a stream of crypto-crystalline muscovite. This is clear when the actual slice

is examined. There is no faulting or dislocation. The biotite has much more powerful action on the actinic rays than muscovite, and consequently the crypto-crystalline biotite comes out with exaggerated hardness.

Fig. 15 shows another remarkable case in which crypto-crystalline muscovite (*a*) (*b*) (*c*) has intruded into a large orthoclase very much in the way, as we have seen in the other illustrations, that the tessellated quartz intruded into other minerals.

The fact that partial refusion took place when the granite was moved up from plutonic depths towards the surface could be proved by numerous examples were it desirable to multiply my illustrations. I could show felspars quietly melting down in various stages of corrosion; but I shall content myself with giving, in conclusion, an illustration (Fig. 16) of the case of a plagioclase (*a*) (apparently oligoclase) embedded in microcline (*b*) (*b*). Here the refusion, or the contact action of the heated microcline on the oligoclase, has resulted in the surface fusion of the oligoclase with the formation of water clear felspar (*c*). This action—for it is not a case of zonal structure—has not only affected the whole of the surface of the oligoclase, but has extended through the centre of the crystal along what was probably a plane of Carlsbad twinning. Suggestions of the original albite twinning can also be made out in the unfused parts of the mineral.

In conclusion, I may say that a consideration of the whole of the evidence, some samples of which I have placed before you, has led me to the conclusion that the structures seen in the Himalayan granite are only to be explained by considering the whole history of the granite from its partial crystallisation at plutonic depths; its incomplete re-solution on being moved upwards into position; and the effects of lateral compression and upward pressure during all the stages of its final consolidation *in situ*. No one cause, taken alone, suffices to explain the characteristic structures alluded to. The foliation, or, in other words, the parallelism in the arrangement of the mica is due in part to traction, and in part to compression prior to the consolidation of the rock. The crypto-crystalline structure of the mica and the tessellated structure of the quartz are due to the partial re-solution of the mica and of the quartz of first consolidation, combined with rapid re-crystallisation during the last stage of consolidation.

For explanation of Plates VIII, IX, and X, see the Plates themselves.

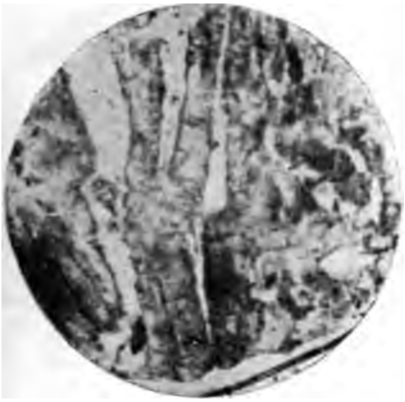


FIG. 1.
Tessellated quartz invading orthoclase.

FIG. 2.
Tessellated quartz corroding and invading microcline. (Seen in polarised light.)

FIG. 3.
Tessellated quartz corroding and invading orthoclase. (Seen in polarised light.)

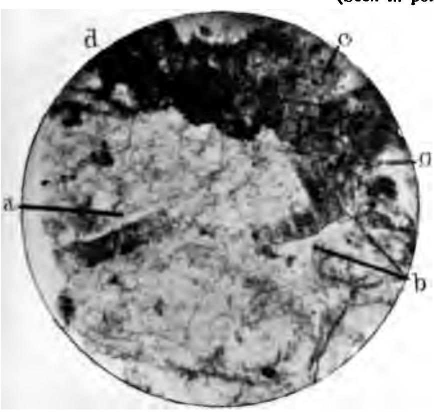


FIG. 4.
Tessellated quartz detaching and floating off fragments of felspar. (*a*) (*b*) Fragments of felspar. (*c*) (*c*) Felspar. (*d*) Matted flakes of biotite.

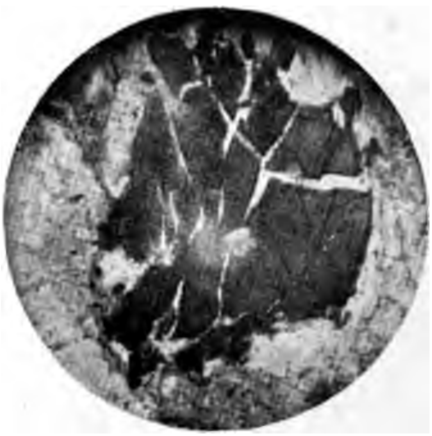


FIG. 5.
A cracked schorl penetrated by tessellated quartz.

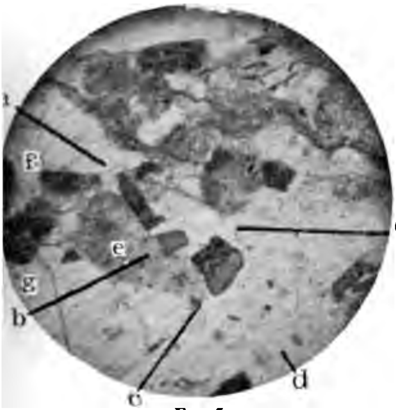


FIG. 6.
cracked schorl penetrated by tessellated quartz. (*a*)(*b*)(*c*) Pieces of a broken schorl. (*d*) Tessellated quartz. (*e*)(*f*)(*g*) Felspar.

FIG. 7.
Streams of crypto-crystalline mica in granite at its junction with slates.

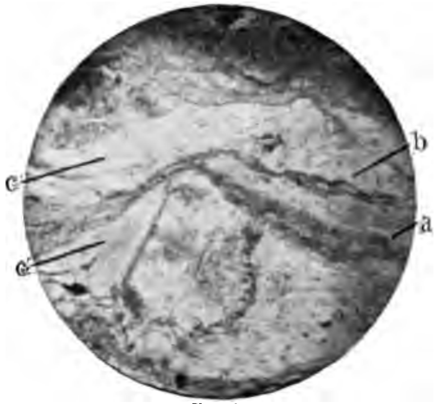


FIG. 8.
A crystal of felspar standing up in a stream of crypto-crystalline mica and tessellate quartz. (*a*) Crypto-crystalline muscovite. (*b*) Crypto-crystalline biotite. (*c*)(*c*) Tessellated quartz.

FIG. 9.
Felspars and quartz crystals in contorted streams of tessellated quartz and crypto-crystalline biotite.

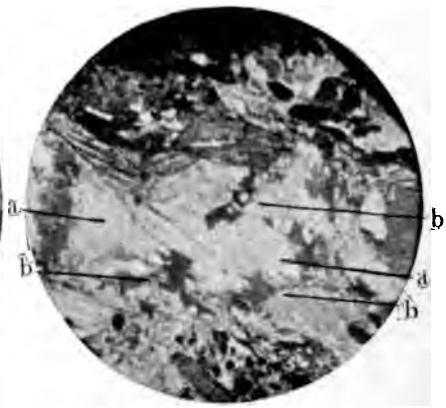


FIG. 10.
A large muscovite corroded and nearly cut across by tessellated quartz. (Seen in polarised light.) (*a*)(*a*) Muscovite. (*b*)(*b*)(*b*) Quartz.

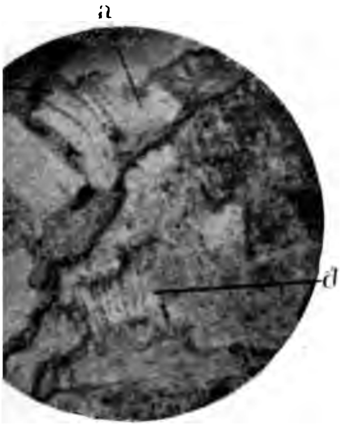


FIG. 11.

tes, (*a*) (*b*) (*c*) and (*d*), in process of being melted down.

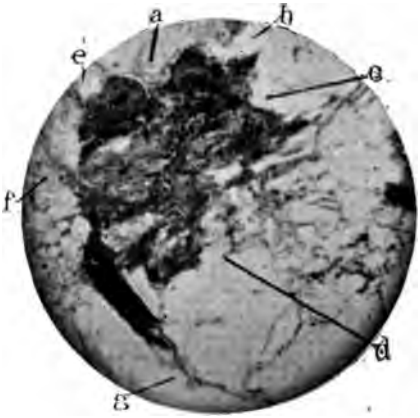


FIG 12.

A biotite suffering from corrosion and solvent action.

FIG. 13.

in tessellated quartz in process of being d down and drawn out into strings.

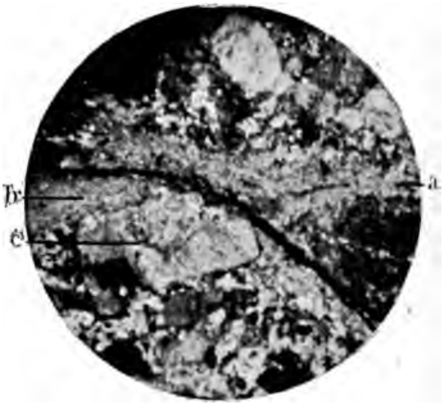


FIG. 14.

A crystal of orthoclase corroded by crypto-crystalline mica. (Seen in polarised light.

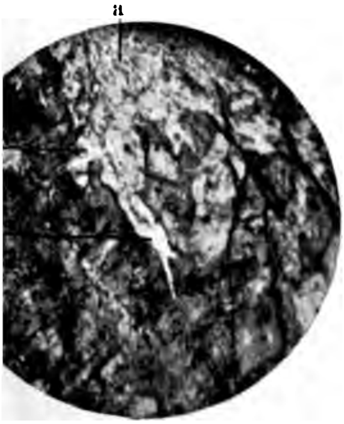


FIG. 15.

rystalline muscovite intrusive in orthoclase.

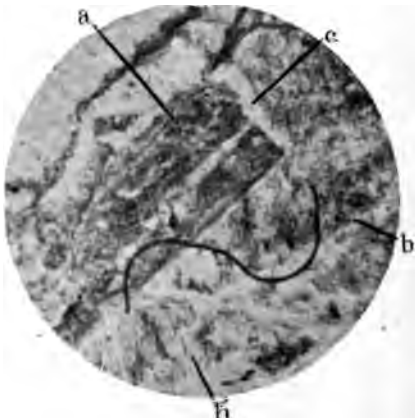


FIG. 16.

Surface fusion of oligoclase imbedded in microcline. (*a*) Oligoclase. (*b*) (*b*) Microcline. (*c*) Water-clear felspar.

ON SOME PLEISTOCENE OSTRACODA FROM FULHAM.

By FREDERICK CHAPMAN, F.R.M.S.

[*Read 6th March*, 1896.]

IN a paper entitled "The Pleistocene (non-marine) Mollusca of the London District," read before the Geologists' Association on the 7th of March, 1890,* Mr. B. B. Woodward gave a list of eleven species of Mollusca from a specimen of clay obtained by the present writer from the eastern end of Bettridge Road, near Hurlingham, the spot being about 600 yards in a direct line from the River Thames. Upon examination, the clay washings yielded numerous valves of Ostracoda. These have now been selected and studied; and as the collection may be useful for comparison with those of other districts, it has been thought worth while to bring it before the Association as a sequel to the list of Mollusca previously mentioned.

The whole of the eight species enumerated are such as inhabit fresh-water streams or muddy and marshy areas.

The material examined also yielded a large number of the nucules (oogonia) of *Chara* sp., as well as fragments of the stems of the same plant, often strongly encrusted with calcareous matter. In these respects the clay resembled other well-known Post-pliocene *Chara*-marls.

The following are the names of the Ostracoda, together with some of the chief references and brief remarks upon the specimens:

CYPRIDIDÆ.

Erpetocypris reptans (Baird).

Candona reptans, Jones, 1856, Monogr. Tert. Entom., p. 16, pl. 1, fig. 7, *a—e*. *Cypris reptans*, Brady, 1868, Monogr. Rec. Brit. Ostrac., p. 370, pl. xxv, figs. 10-14; pl. xxxvi, fig. 4. *Erpetocypris reptans*, Brady and Norman, 1889, Trans. R. Dublin Soc., ser. II, vol. iv, p. 84.

Two valves from Pleistocene clay, Fulham.

Candona candida (Müller).

C. candida, Jones, 1856, Monogr. Tert. Entom., p. 19, pl. 1, figs. 5, *a*, *b*; 8, *a*, *f*. Brady and Norman, 1889, Trans. R. Dublin Soc, ser. II, vol. iv, p. 98, pl. x, figs. 1, 2, 14-23.

* See *Proc. Geol. Assoc.*, vol. xi, 1889-90, p. 341. Mr. Woodward now prefers the word "Holocene" instead of "later (or Neolithic) Pleistocene" for this deposit.

A few of the examples selected closely approach the variety *claviformis** and *Candona elongata*† of the last-named authors.
Common, Pleistocene clay, Fulham.

Candona lactea, Baird.
C. lactea, Brady, 1868, Monogr. Rec. Brit. Ostrac., p. 382, pl. xxiv, figs. 55-58. *C. detecta*, Brady, Crosskey, and Robertson, 1874, Monogr. Post-tert. Entom., p. 134, pl. I, figs. 7-9. *C. lactea*, Brady and Norman, 1889, Trans. R. Dublin Soc., ser. II, vol. iv, p. 100.
The two differently-shaped carapaces formerly relegated to the above separate names are now united under one name. Both of these forms were met with in nearly equal proportion in the clay from Fulham, and are very common.

Candona pubescens (Koch)
Cypris pubescens, Koch, 1837, Deutschlands Crustaceen, etc., H. 11, p. 5. *C. setigera*, Jones, 1856, Monogr. Tert. Entom., p. 12, pl. I, fig. 6 *a—d*. *Canaona compressa*, Brady, 1868, Monogr. Rec. Brit. Ostrac., p. 382, pl. xxvi, figs. 22-27. *C. pubescens*, Brady and Norman, 1889, Trans. R. Dublin Soc., ser. II, vol. iv, p. 101.
The above form is fairly common in the clay from Fulham. The valves are in some cases sparsely clothed with the setæ characteristic of living examples.

Candona albicans, Brady.
C. albicans, Brady, 1864, Ann. and Mag. Nat. Hist., vol. xiii, p. 61, pl. iv, figs. 6-10. Brady, Crosskey, and Robertson, 1874, Monogr. Post-tert. Entom., p. 133, pl. I, figs. 10-18.
This form was placed by Brady and Norman in 1889 (*op. cit.*, p. 101) in the synonomy of *C. pubescens* (Koch), on account of the probability of its being the young of that species, or of *C. rostrata*, Brady and Norman. The specimens here under discussion show marked variations amongst themselves, and whilst some are no doubt referable to *C. pubescens*, others are undoubtedly the young stage of *Ilyocypris gibba* (Ramdohr). On account of its questionable position it is here referred to by the old name.
This appears to be the most abundant form amongst the Ostracoda from Fulham.

Ilyocypris gibba (Ramdohr).
Cypris gibba, Ramdohr, 1808, Magaz. d. Gesellch. Naturforsch. Freunde zu Berlin, II, p. 91, pl. III, figs. 13-17. Jones, 1856, Monogr. Tert. Entom., p. 15, pl. I, figs. 3 *a—f*; woodcut, fig. 1,

* Brady and Norman, *op. cit.*, p. 99, pl. x, figs. 1, 2.
† Iidem, *ibid.*, p. 100, pl. x, figs. 24, 27.

p. 16. Brady, Crosskey, and Robertson, 1874, Monogr. Post-tert. Entom., p. 127, pl. xv, figs. 5, 6. *Ilyocypris gibba*, Brady and Norman, 1889, Trans. R. Dublin Soc., ser. II, vol. iv, p. 107.

This Ostracod is well-known as a Pliocene, Post-pliocene, and Recent form. It has been assigned by Brady and Norman to the genus *Ilyocypris* on account of its peculiar habit of crawling upon the surface of the mud.

The specimens from Fulham are exceedingly fine and characteristic. It has already been noted in this paper that some of the valves described under the name of *Candona albicans* may be regarded as the young of this species.

CYTHERIDÆ.

Limnicythere inopinata (Baird).

Cythere inopinata, Baird, 1850, Brit. Entom., p. 172, tab. xx, figs. 1, 1 *a—e*. *Limnicythere inopinata*, Brady, Crosskey, and Robertson, 1874, Monogr. Post-tert. Entom., p. 173, pl. x, figs. 8-11; pl. xxxviii, fig. 9; pl. xxxix, fig. 1.

This is a very striking form in its outline and sculpturing. In some of the specimens the flanges of the posterior and anterior extremities are flattened out to a large degree, so that they closely approach the variety *compressa* of Brady and Norman.*

The species is common in the Pleistocene clay from Fulham.

(?) *Cytheridea torosa* (Jones).

Candona torosa, Jones, 1850, Ann. and Mag. Nat. Hist., ser. 2, vol. vi, p. 27, pl. iii, fig. 6. *Cytheridea Mulleri* var. *torosa*, Jones, 1856, Monogr. Tert. Entom., p. 42, pl. vi, fig. 12. *C. torosa*, Dahl, 1888, Die Cytheridea der Westlich Ostsee, p. 16, pl, i, fig. 31, pl. ii, figs. 32-48.

Three small valves occurred in the Pleistocene clay at Fulham, which apparently belong to this species, but as the hingement was somewhat obscure there may be a slight doubt as to their true generic affinities; although one specimen afforded some slight evidence of knurling along the hinge-line.

In concluding these notes, I acknowledge my obligations to to Prof. T. Rupert Jones, F.R.S., for valuable advice.

* Trans. R. Dublin Soc., ser. II, vol. iv, 1889, p. 170, pl. xvii, figs. 18, 19.

VISIT TO THE BRITISH MUSEUM (NATURAL HISTORY), CROMWELL ROAD.

SATURDAY, 14TH MARCH, 1896.

Director: A. SMITH WOODWARD, F.L.S., F.G.S.

(*Report by* THE DIRECTOR AND EXCURSION SECRETARY.)

Members assembled in the Entrance Hall at 3 p.m.

The Director conducted the party through the Geological Galleries, and gave the following account of the Fossil Fishes:

The Association last inspected the collection of Fossil Fishes on March 15th, 1884, shortly after the Egerton and Enniskillen Collections had been incorporated. Since that date nearly 7,000 specimens have been added, the majority having been obtained from important private collections purchased by the Trustees, and a few very valuable specimens acquired by donation.

The principal private collections presented since 1884 are those of the late John Edward Lee, Esq., F.G.S. (general, but comprising especially fine Pteraspidians and Cephalaspidians), of George H. Piper, Esq., F.G.S. (unique Cephalaspidians from the Lower Old Red Sandstone Passage Beds of Ledbury), of S. J. Hawkins, Esq., F.G.S. (remains from Chalk of Burham), and of P. E. Coombe, Esq. (various specimens from the Chalk and Eocene of Sussex).

The more important private collections purchased since 1884 are eleven in number. That of the late Rev. Hugh Mitchell, LL.D., consists of fish-remains from the Lower Old Red Sandstone of Forfarshire; that of John Ward, Esq., F.G.S., is the unique series of fishes from the Coal Measures of Staffordshire, on which nearly all researches in reference to Upper Carboniferous Ichthyology in this country have hitherto been based. The latter is supplemented by the comparatively small Weston Collection, also from the Coal Measures of North Staffordshire. The collection of the late James W. Davis, Esq., F.G.S., comprises numerous fragmentary fish-remains from the Yorkshire Coal Measures, and many fine Liassic fishes from Lyme Regis; that of the Rev. P. B. Brodie, M.A., F.G.S., includes many type and figured specimens from the Keuper, Lias, and Purbeck Beds. The fishes from the Oxford Clay of Peterborough, forming the collection of Alfred N. Leeds, Esq., F.G.S., are unique, and add much to our knowledge of the skeleton of the Upper Jurassic

genera. The collection of the late Samuel H. Beckles, Esq., F.R.S., F.G.S., chiefly consists of Wealden fishes from the neighbourhood of Hastings, but also includes a fine slab of Upper Old Red Sandstone from Dura Den displaying *Holoptychius Flemingi*, and a block of Chalk containing a unique group of *Hoplopteryx*. The Wealden series is supplemented by the small collections of Charles Dawson, Esq., F.G.S., and of Peter Rufford, Esq. Fish-remains from the Cambridge Greensand have been acquired from the collection of Thomas Jesson, Esq., F.G.S.; and the great collection of beautiful Cretaceous fishes from Mount Lebanon was made by the Rev. Prof. E. R. Lewis, late of the Syrian Protestant College, Beyrout. The series of English Chalk fishes worked out of the matrix by the late Frederick Harford, Esq., may also be noted.

Among miscellaneous purchases many fine fishes from the Lithographic Stone of Bavaria, a large slab of *Portheus* from the Chalk of Kansas, and an extensive series of Devonian fishes from Canada in an unusual state of preservation deserve notice.

The incorporation of these numerous acquisitions has involved much re-arrangement of the cases, and the preparation of the official "Catalogue," of which three volumes have already appeared, has also resulted in some changes in the system of classification. A synopsis of the new arrangement is given in the accompanying table (p. 304), in which the brackets to the right indicate the limits of the orders in the more familiar grouping.

On the motion of the President a most cordial vote of thanks was given to Mr. Smith Woodward for his kindness in acting as Director, and for his interesting demonstration.

SUB-CLASS I.—ELASMOBRANCHII. Jaw-apparatus suspended from skull; no operculum; dermal armour without bone-tissue ... ... Order I.—PROSELACHII. Paired fins supported by parallel rods of cartilage; no claspers in male ... ... Order II.—ICHTHYOTOMI. Pectoral fins supported by cartilages radiating from central axis; claspers in male ... ... Order III.—ACANTHODII. All fins except caudal with spine in front, and cartilages very short; no claspers ... ... Order IV.—SELACHII. Pectoral fins with two or three basal cartilages and no central axis; claspers in male ... ... Sub-orders. *Tectospondyli* and *Asterospondyli* SUB-CLASS II.—HOLOCEPHALI. Jaw-apparatus fused with skull; an opercular membrane; dermal armour without bone-tissue ... ... Order I.—CHIMÆROIDEI. Fins as in Selachii ...	Elasmobranchii or Chondropterygii.
SUB-CLASS III.—DIPNOI. Jaw-apparatus fused with skull; an opercular bone; dermal armour often with bone-tissue ... ... Order I.—SIRENOIDEI. Scaly fishes with paddle-shaped paired fins, these supported by a segmented axis	Dipnoi.
Order II.—ARTHRODIRA. Armoured fishes, the head-shield hinged on body-shield; paired fins rudimentary ... ... SUB-CLASS IV.—TELEOSTOMI. Jaw-apparatus suspended from skull; an opercular bone; dermal armour often with bone-tissue ... ... Order I.—CROSSOPTERYGII. Paired fins paddle-shaped and fringed with fin-rays ... ... Sub-orders. *Haplistia*, *Rhipidistia*, *Actinistia*, and *Cladistia* ... ... Order II.—ACTINOPTERYGII. Supports of paired fins much shortened and dermal rays chiefly supporting membrane ... ... Sub-orders. *Chondrostei*, *Protospondyli*, *Aetheospondyli*, *Isospondyli* (in part)	Ganoidei.
Isospondyli (continued), *Plectospondyli*, *Nematognathi*, *Haplomi*, *Apodes*, *Anacanthini*, *Percesoces*, *Pharyngognathi*, *Percomorphi*, *Lophobranchii*, *Hemibranchii*, and *Plectognathi*	Teleostei.

EXCURSION TO GALLEY HILL, NEAR NORTHFLEET, AND SWANSCOMB HILL.

SATURDAY, MARCH 28TH, 1896.

Directors: THE PRESIDENT (E. T. NEWTON, F.R.S.), F. C. J. SPURRELL, F.G.S., AND H. STOPES.

Excursion Secretary: H. A. ALLEN, F.G.S.

(*Report by* THE PRESIDENT.)

ALTHOUGH the weather was very inclement, a good number of members left Cannon Street by the 2.15 train for Northfleet, and walked to the Chalk and Gravel pit at Galley Hill, where they were met by the manager of the works, Mr. John Hoyle. After the party had made a preliminary examination of the pit and Palæolithic gravel, the President gave an account of the geological position and surroundings of the gravel, under 8 or 10 feet of which the human remains recently described (*Quart. Journ. Geol. Soc.*, August, 1895) had been found.

The Chalk at Galley Hill rises about 80 or 90 feet above the Thames, and is capped by a loamy gravel which, at this spot is about 10 feet thick and is covered by 2 or 3 feet of made earth. This patch of gravel continues for about a quarter of a mile to the south, and is nearly a mile in extent from east to west; including within this area the famous pits of Swanscomb and Milton Street, as well as Galley Hill; in all three pits Palæolithic implements have been found in considerable numbers.

This gravel is part of the sheet of High-terrace gravel which, at about the same height, extends over the Chalk from Northfleet westwards to Dartford, and is at a much higher level than the Brickearths of Crayford and Grays, while the Plateau gravel of Prestwich, which is said to extend northward to Swanscomb Hill, is at a still higher level.

The face of the gravel in the pit has been cut back some 10 feet since the discovery of the skeleton; but the Chalk platform remains, and the position of the remains above the Chalk was pointed out by their discoverer, Mr. Robert Elliott.

The characters of the skeleton were then briefly described, especial reference being made to the length of the skull, to its strongly-developed brow ridges, and to the large and equal size of the three molar teeth. The question as to the antiquity of these remains, and the possibilities of error, was very fully

discussed, and the President said he had come to the conclusion that it is in the highest degree probable that the skeleton is really of Palæolithic age.

Mr. F. C. J. Spurrell gave some further account of these gravels, which, he said, were undoubtedly Palæolithic, and alluded to the condition of the mammalian remains which had been found in other pits in the neighbourhood at the same horizon. He was inclined to accept the human remains as contemporaneous with the gravels.

Mr. R. Elliott gave a short account of the finding of the remains.

Mr. Spurrell, being unable to remain with the party, Mr. H. Stopes kindly undertook to conduct the members to the top of Swanscomb Hill; and, as they ascended over the slippery clay, he pointed out the position of certain of the Lower Tertiary beds, of which the hill is formed; and also a mound of Neolithic age, from which many flint flakes were obtained by some of the party. On arrival at the summit the peculiar gravelly soil was examined, and doubt was expressed as to this being part of the Plateau gravel. The party then descended to the village of Swanscomb, where Mrs. Stopes had very hospitably provided tea, which the damp and cold weather made all the more acceptable. After tea, Mr. Stopes' fine collection of flint implements was inspected, and much appreciated.

Very cordial thanks were given to Mr. J. Hoyle and to Mr. Spurrell before the party left the Galley Hill Pit; and, later on, to Mrs. and Mr. Stopes for their hospitality. A walk to Northfleet Station concluded the excursion.

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1889. WHITAKER, W.—"Geology of London." *Mem. Geol. Survey.*
1890. SPURRELL, F. C. J.—*Proc. Geol. Assoc.*, vol. xi, p. cxlv.
1891. PRESTWICH, J.—*Quart. Journ. Geol. Soc.*, vol. xlvii, p. 126.
1895. NEWTON, E. T.— „ „ „ „ vol. li, p. 505.

EXCURSION TO SWANAGE, CORFE CASTLE, KIMERIDGE, ETC.

EASTER, 1896.

Directors: W. H. HUDLESTON, F.R.S., REV. OWEN L. MANSEL, and H. W. MONCKTON, F.L.S., F.G.S.

(*Report by* THE DIRECTORS.)

PART I.—BY MR. MONCKTON.

THE headquarters during the whole of this excursion were at the Grove Private Hotel, Swanage, where a large number of members assembled on the evening of Thursday, April 2nd. Mr. E. P. Ridley, F.G.S., was the member of the Excursion Committee to whom the arrangement of the Excursion was entrusted.

Friday, April 3rd.—Mr. Monckton acted as Director. The party drove from Swanage, through Langton Matravers, and Worth Matravers, to Renscombe Farm, and walked by way of West Hill to Chapman's Pool. On the way the Director made a few remarks on the general geology of the district, and pointed out the more important features of the magnificent cliff sections in view.

He remarked that during the Easter Excursion of 1895 he had had an opportunity of addressing the members at Sandown, in the Isle of Wight. On that occasion he drew special attention to the great anticline of the Isle of Wight, which, due to a post-cretaceous disturbance, commences in Weymouth Bay, and runs out to sea east of the Isle of Wight. The party were at that time close to the top of the anticline, which is there formed of the Wealden Beds. To-day they found themselves about forty miles west of Sandown, still on the line of the same great disturbance. They were, however, standing upon strata of greater age than the Wealden, for that series cropped out north of the road along which they had come, and during the whole drive they had been on beds of Purbeck age.

Now they were upon the Portlandian, and the Kimeridge clay was seen in the cliffs and on the shore of Chapman's Pool below them. (See Fig. 2, p. 311.)

At Sandown they had seen the southern side of the anticline in the cliffs between that place and Shanklin, but here it had been destroyed by the advancing sea.

The Director further remarked on the curious fact that here, as in the Isle of Wight, the streams showed a tendency to flow away from the south coast, through the chalk to the north, and expressed his belief in the theory that they had formerly been tributaries running off the northern side of the anticline to a

great river which, starting with the Frome, crossed what is now sea between Poole and the Solent, and flowed away to the east, following the line of the syncline which runs east and west north of the great anticline.

Chapman's Pool has long been a noted locality for Kimeridge clay fossils. It is referred to in our "Proceedings" as long ago as 1876, in a paper by W. R. Brodie,* and was visited by the Association on Whit Monday, 1882; but the visit appears to have been a very hurried one.†

On the present occasion ample time was allowed for collecting, and the President, Mr. E. T. Newton, noted amongst the fossils found:

Ammonites biplex.	*Lucina minuscula (?).*
Arca (small species).	*Cardium striatulum.*
Astarte (Lucina) lineata.	*Pollicipes.*

Unfortunately the Ammonites here are, for the most part, crushed, but portions of the outer whorl were in several cases found in an uncrushed condition.

Leaving Chapman's Pool, the party walked along a beautiful piece of undercliff formed by the slipping of the Portland Beds over the Kimeridge clay, and ascending the cliff by the coast-guards' path, lunched in a grassy hollow near St. Alban's Head. After lunch the members walked on to the Head, and noticed, in passing, the interesting old chapel close to the coast-guard station. They then examined an old quarry on the brow of the cliff, and some time was spent in collecting Portland fossils, the following forms being noted—*Cardium dissimile*, *Pecten lamellosus*, *Pecten* sp., *Trigonia muricata*, and *T. tenuitexta*, and a large oyster. On the new edition of the one-inch Geological Survey map a much greater extension of the Lower Purbeck is shown at St. Alban's Head than on the old edition. According to the new reading, the basement bed of the Purbecks runs along the brow of the cliff towards the east from the coast-guard station. Leaving St. Alban's Head the party proceeded along the top of the cliff towards Swanage, and it is worthy of note that from the Head onwards the members were, it is believed, on ground never before visited by the Association.

The linchets, or ancient cultivation terraces, described and illustrated by Mr. H. B. Woodward (*Geology of England and Wales*, 2nd edition, pp. 607, 609, Fig. 100), attracted much attention, and gave rise to some discussion. On the surface of a field near the cliff one of the party picked up a fragment of silicified wood, probably coniferous.

There was a short halt at Winspit Quarry, and the members then continued their way along the cliff to a quarry at Seacomb, where some time was spent, and several fossils were found,

* *Proc. Geol. Assoc.*, vol. iv, p. 517.
† *Record of Excursions*, p. 329.

FIG. 1.—SECTION FROM DURLSTON HEAD TO PEVEREL POINT, SWANAGE.—*A. Strahan.*

3. Marls with gypsum } Lower Purbeck.	8. Corbula and Beef Beds } Middle Purbeck.	10. Purbeck Marble, etc. } Upper Purbeck.
2. Caps	7. Stone Beds	9 Burr Limestone, etc.
1. Portland Stone.	6. Cinder Bed with *Ostrea distorta*	
	5. Stone Beds	
	4. Flint Bed, Black Shale and Mammal Bed	

including: *Cyprina implicata*, *Pecten lamellosus*, and *Pleuromya tellina*.

The representative of the Tilly Whim oyster-bed was clearly seen. It contained numbers of shells of Perna.

The base of the Lower Purbeck runs along the edge of the cliff; and there are numerous old workings in the Middle Purbeck on the hill-side to the south.

The party proceeded as far as Durlston Head, where tea was found at the so-called Durlston Castle. After tea the members returned to Swanage.

Saturday, April 4th.—Mr. H. W. Monckton again acted as director, and conducted the party to Durlston Bay. Most of the morning was spent in an examination of the splendid sections in the Upper, Middle, and Lower Purbecks shown in the cliffs. Unfortunately the state of the tide was unsatisfactory, and prevented full justice being done to the highly fossiliferous strata. The President's note of finds is as follows:

Durlston Bay. Purbecks.

Turtle (plates and bones).
Goniopholis (scales and teeth).
Lepidotus (teeth).
Mesodon (teeth).
Hybodus, 2 species (teeth).
Corbula alata.
Cyrena media.
Ostrea distorta (Cinder bed).
Paludina carinifera.
Entomostraca (from cherty layers below Cinder).

Mr. Hudleston's account of the visit to this locality on May 30th, 1882, is so good that it seems unnecessary to add anything further.*

* *Record of Excursions*, p. 331

From Durlston Bay the members walked to the "caves" of Tilly Whim, which do not seem to have been visited in 1882. The "caves" are really old free-stone quarries, and Mr. William Brindley, F.G.S., gave an interesting account of the various building stones of the Isle of Purbeck, and the methods of working them. The photographs reproduced on Plate XI give a very good idea of the Tilly Whim caves, and in the lower one (B) Durlston Head is seen in the distance. The section at Tilly Whim is as follows:

1. Oyster or Perna Bed, about twelve feet thick at the west end, a great mass of oysters and numerous specimens of *Perna Bouchardi* occurs. A large fallen mass from this bed is seen in the foreground of Plate XI, B.

2. Limestone, about ten feet thick, extremely hard. It appears to represent the stone which is worked at St. Albans Head, close to the coast-guard station, but has not been worked at Tilly Whim.

3. Shelly bed, about three feet thick, which forms the roof of most of the old chambers and levels. A large Ammonite, probably *A. giganteus*, was seen *in situ* about nine inches above the bottom of this bed. It was pointed out to the Director by Mrs. Hudleston.

4. The freestone which has been worked here. It is eight feet or more thick.

5. The chert series, which is very well seen at Tilly Whim, and is over twenty-five feet thick. Sponge spicules were noticed in the chert by the President.

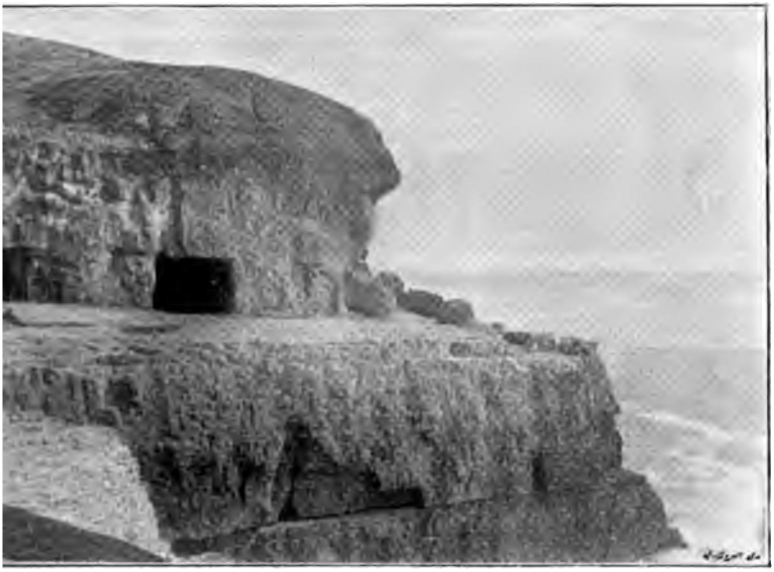
6. Limestone—a specimen of *Ammonites giganteus* was seen *in situ* below high-water mark.

After a halt for lunch at Durlston "Castle," the members visited a small quarry in the hillside above Tilly Whim. It is about 250 feet above the sea, and in it the Middle Purbeck Cinder Bed (No. 6 of Fig. 1) is very well shown. The Middle Purbeck building-stone below the "Cinder Bed" has been worked by a level, and among the debris at the mouth the President found specimens of flinty chert, with *Chara* stems and Ostracoda in some abundance.

The members then walked across the fields to the north, and visited a quarry in the Middle Purbeck which was being worked by the method so well shown in the sketch in H. B. Woodward's *Geology of England and Wales* (2nd edit., p. 350, Fig. 55).

The workmen produced out of little huts, just like those in the sketch, some fragments of the stone, with bones and plates of turtle, masses of scales of *Lepidotus*, and teeth and spines of *Hybodus*.

This completed the programme for the day, but as the weather was beautifully fine and there was plenty of time to spare,



6

A.—The Tilly Whim "Caves," Swanage.
(For explanation of numbers, 1 to 6, see p. 310.)

B.—Durlston Head, from Tilly Whim, Swanage.

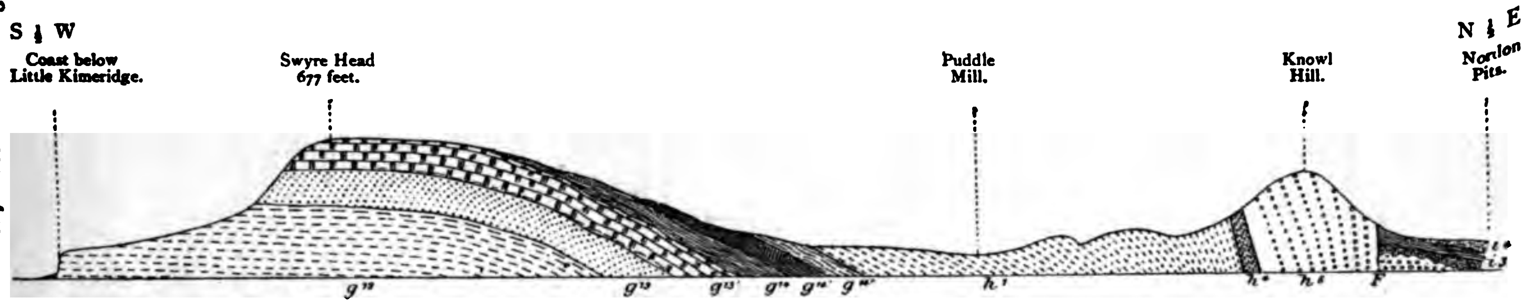


FIG. 2.—DIAGRAMMATIC SECTION ACROSS PART OF THE MIDDLE OF THE ISLAND OF PURBECK.—*W. H. Hudleston.*

(Length of Section rather over 3½ miles.)

The line of this section is about a mile west of the meridian of Corfe Castle, and strikes the coast half-way between Kimeridge Bay (west) and Chapman's Pool (east). The Upper Kimeridge alone is exposed, dipping eastward away from the anticlinal of Kimeridge Bay, which is transverse to the main axis of curvature. The beds on the Purbeck slope are more irregular than is shown in section. The thickness both of the Purbecks and Wealden rapidly diminish towards the west, and this rule applies to all the beds below the Chalk. In the new map there is no fault shown on the north side of the Chalk ridge, but this is a point on which opinions still differ. In any case the dip of the Tertiary beds is probably somewhat different to what is shown in the diagram.

EXPLANATION OF SIGNS.

g^{12}. Kimeridge Clay. g^{13}. Portland Sand. $g^{13\prime}$. Portland Stone. g^{14}. Lower Purbecks. $g^{14\prime}$. Middle Purbecks. $g^{14\prime\prime}$. Upper Purbecks. h^{1}. Wealden Beds and Lower Greensand. h^{4}. Upper Greensand (with Gault?). h^{5}. Chalk. i^{2}. Reading Beds. i^{3}. London Clay. i^{4}. Bagshot Beds.

N.B.—The Lower Greensand (h^{2}) ought to be shown as distinct from the Wealden.

some of the party went crocodile-hunting to Peveril Point, and others accompanied the Director to Punfield Cove.

The cliff section here was visited during the 1882 Excursion, and a full account will be found in the *Record of Excursions*, p. 333. It was again visited in 1894.*

The following fossils were collected:

LOWER GREENSAND (Fossiliferous limestone with marine shells, Bed C of Meÿer).

Ostrea.	*Cerithium.*
Melania ? (Vicarya ?)	*Meyeria.*

UPPER GREENSAND.

Spondylus striatus.	*Echinocyphus (?).*
Gryphæa vesiculosa.	*Terebratella pectita.*
Vermicularia concava.	*Turrilites (?).*

LOWER (?) CHALK (fallen blocks).

Inoceramus mytiloides.

Mr. T. Leighton, F.G.S., also found several casts of *Panopæa* in a clayey bed in the Lower Greensand, top of bed F of Meÿer's section (*Quart. Journ. Geol. Soc.*, vol. xxix, p. 72).

PART II.—BY MR. HUDLESTON.

Monday, April 6th.—The party drove from Swanage to Corfe Castle, and leaving the carriages, walked into the yard of the railway station, where there is a small but most interesting section in the fossiliferous beds of the Lower Greensand. A few fossils were obtained, and the members walked to the castle, where they were met by Mr. Hudleston, who acted as Director. After passing through the inner gateway, where the outer tower has slipped downwards and forwards in a way curiously imitative of a regular fault, they proceeded towards the south-west corner of the castle grounds, in order to inspect certain remains of Saxon architecture which have here been built into the outer wall. The Director reminded the members that, although much of the celebrity of the castle is due to events which took place in Saxon times, the keep is of early Norman date, whilst other portions of the structure belong to the time of the Plantagenet kings. Many of the victims of King John were imprisoned here, and the place remained a royal fortress down to the days of Elizabeth. Ultimately it came into the hands of the Bankes family, with whom it has remained for considerably over two centuries.

Mr. Parker then gave a short but extremely interesting account of the main features of the castle, and said a few words as to its history; after which, and before leaving the *enceinte* of the castle, the Director drew attention to its geological position, and incidentally to the diagrammatic section across the Isle of Purbeck (Fig. 2),

* *Proc. Geol. Assoc.*, vol. xiii, p. 278

for which he was partly responsible. This section had been plotted fourteen years ago from the old Survey map, which showed a fault along the north side of the Chalk ridge, at its junction with the Tertiary Beds. In a recent survey by Mr. C. Reid and Mr. Strahan, no fault is shown in this position. As the junction of the Chalk and Tertiaries, within the Isle of Purbeck, did not form any portion of the programme of the Excursion, he would make no further observations on this point.

On referring to the report of the previous excursion*, it would be seen that at the Matcham Clay Works, in the Lower Bagshots, which are close to the Corfe gap (occupying the position of the Nordon pits in the diagram), there is a dip of 15° to the south, which is exactly the reverse of the normal Purbeck dip. The next exposure towards the south is that of the Upper, or *Belemnitella* Chalk, in the quarry just below the monticle on which the castle stands. This is seen to dip at a high angle to the north. The monticle itself consists of the remainder of the Upper, together with the Middle and Lower Chalk, tilted at a very high angle towards the north. He had lately found traces of the Chloritic Marl, with *Am. varians*, whilst in the outer ditch Upper Greensand might yet be seen; and there is no doubt that a large portion of this ditch had been excavated in that formation. Of the Gault, as a distinct clay formation, he had not himself obtained evidence in this traverse, but there could be no doubt that beds of Lower Greensand age, tilted at a high angle, were largely developed. In fact, a considerable portion of the town of Corfe Castle stands upon Lower Greensand. This fact was made more clear owing to the wide cutting where the railway station is situated, as the members had already been able to verify. The exposure near the railway station is very fossiliferous, and the beds underneath the manor-house are stated to contain a similar set of fossils. A somewhat cursory search had served to yield about twenty species of Mollusca, including *Am. Deshayesii*, *Vicarya*, and a large *Corbis*, all three eminently characteristic of the horizon.

The party then proceeded in carriages towards Kimeridge, the route throughout the first part of the journey lying in the longitudinal hollow represented by the Wealden beds. On crossing the Puddle brook the carriages began to slant up the long slope of Purbeck beds, until they achieved the crest overlooking the village of Kimeridge, from which point they were sent round to meet the party at Worbarrow, in the afternoon. The members themselves rapidly descended the steep hill, and in passing through the picturesque little churchyard of Kimeridge, attention was drawn to the recent grave of Colonel Mansel, the late owner of this property, whose hospitable intentions towards the Association were only frustrated by his sudden death.

* *Proc. Geol. Assoc.*, vol. vii, p. 378; *Record of Excursions*, p. 321.

A smart walk on the soft greensward, skirting Kimeridge Bay, brought the party to the cleft in the precipice where the life-boat used to be kept. Taking advantage of the shelter, a halt was called for lunch. At this point a good view is obtained of the Kimeridge ledges, together with the system of faulting, for which the west side of the Bay is so remarkable. But as time pressed, and the state of the tide was somewhat unfavourable, the Director led the party without any further delay to the "Broad Bench," a rock-platform which projects like a low tongue between Kimeridge and Hobarrow Bays.

There is no point on the whole coast of the Isle of Purbeck where so much is to be seen. It commands the greater part of the enormous development of Kimeridge Clay, with its interesting stratigraphical features on both sides of the anticlinal. Facing the land, you have on the right the whole extent of Kimeridge Bay, terminated on the east by the precipices of Hencliff, where the Upper Kimeridge beds are seen dipping at a moderate angle towards the south-east in the direction of St. Albans Head. The curve of Kimeridge Bay itself is bounded by a low but precipitous cliff, where the hard beds between the softer shales serve to mark the stratigraphy; these hard beds form the Kimeridge ledges, of which a great extent are bare at low spring tides. The general dip in the Bay is to the south-east; but as the west side of the Bay is approached the axis of this local anticline, or "*bombement*," makes itself felt in a series of faults with downthrow to the south-east, whereby the Bench-rock, on which the party were now standing, is repeated several times on the sea-floor.

On the left, in Hobarrow Bay, the prospect is still more remarkable, for not only are the geological features interesting, but the scenery is of the most impressive character. In the immediate foreground stretches the deep little inlet of Hobarrow Bay, bounded by precipitous cliffs of shale and stone-bands, which mark the Kimeridge beds of this region. At the head of this inlet is the last fault in connection with this upthrust, and here the lowest beds in the Isle of Purbeck are brought to day (see Fig. 3). Thenceforth there is a steady and rapid dip of all the Kimeridge beds towards the north-west until they pass beneath the Portland Sand at Brandy Bay, which itself is seen to support the mural cliffs of Portland rock culminating in the noble precipice of Gad Cliff (see Fig. 4).

The Director congratulated the members present on having achieved a fresh piece of work in the investigation of the classic locality of Kimeridge Bay, hitherto unvisited by the Association. The occasion was all the more fortunate from the circumstance that the President, who conducted the party, happened to be the Palæontologist to the Geological Survey; since so many of the questions connected with this subject were of a palæontological nature. The Director alluded to the peculiarly irregular develop-

ment of the Kimeridge Clay, than which, as he had often maintained, there is no formation in the whole Jurassic system more difficult to "tabulate or understand."

This difficulty arises from two principal causes. *Firstly*, the irregularity of the development, which is further increased by a want of definite shell-beds, showing zonal succession, such as characterise the Lias. *Secondly*, from the fact that our Upper Kimeridge is by the French included in their Portlandian, taking Boulogne as the standard. From a French point of view, there are good physical reasons for this, since "Portlandian" conditions set in earlier at Boulogne than in Dorsetshire. At Boulogne (visited by the Association in 1878*) the volume of the marine Jurassic beds above the Corallian is probably not more than a fourth of the thickness they attain in the Isle of Purbeck, but they are more varied and better furnished with recognisable Mollusca. Argillaceous conditions are much less frequent at Boulogne, and more or less terminate with the shales carrying *Exogyra virgula*, which really represent the top of our Lower Kimeridge, though called by Pellat "Upper Kimeridgian." Hence the idea which prevailed for a long time in some quarters, that the "Virgulien" of foreign authors is Upper Kimeridge. The fact is that the "Virgulian," or top of the French Kimeridgian, represents the upper part of our Lower Kimeridge.

What, then, at Boulogne succeeds the Virgulian horizon? Undoubtedly the Lower Portlandian of the French, where arenaceous and even conglomeratic deposits, with a fauna partly modified by the peculiar physical conditions, occur on the horizon of the lower part of our Upper Kimeridge Clay, as developed in the Isle of Purbeck. These beds constitute the Bolonian of Blake. To understand, then, the correlation of our Kimeridge section, we must bear in mind that the Lower Portlandian of the French (Blake's Bolonian) is on the horizon of the *lower part* of our Upper Kimeridge, whilst the Virgulian of the French corresponds, in the main, with the *upper part* of our Lower Kimeridge.

It would be necessary, on the present occasion, to apply the preceding generalisations to the study of the local details, as afforded by the grand sections on the Kimeridge coast. There were three principal points for the consideration of the party.

1. Where to draw the line between the Upper and Lower Kimeridge.

2. To institute a comparison between the beds on the south-east and north-west sides of the Kimeridge Bay anticlinal.

3. To observe the local stratigraphy, especially the faults.

1. *Line between Upper and Lower Kimeridge.*—Owing to the fact of lithological passage and a certain overlap of fauna, the actual line is very difficult to draw. From the base at Hen Cliff

* *Proc. Geol. Assoc.*, vol. vi, p. 39; *Record of Excursions*, p. 537.

to the top of the Kimeridge Clay at Chapman's Pool, there are 650 feet of beds. At least 580 feet of these there can be no hesitation in assigning to the Upper Kimeridge, which contains the workable cement-stone, the Kimeridge coal with its bituminous shales and the fossiliferous beds atop, near Chapman's Pool. The vertebrate fauna of these coaly and sub-calcareous mudstones appears to have been abundant, whilst the molluscan fauna is poor in species, though individuals, chiefly small flattened bivalves, are numerous. *Am. biplex*, *Discina latissima* and *Lucina minuscula* are common and characteristic. Indications of the Hartwell fauna, such as *Belemnites Souichii*, etc., may be expected at Chapman's Pool.

At about 580 feet from the top of the series a change is noted. There is still what is called *Am. biplex*, along with some recognised Upper Kimeridge fossils, but with these are associated the so-called *Am. Thurmanni* and *Exogyra virgula* (now seen for the first time). Thus about seventy feet of beds, down to the base at Hen Cliff, are doubtful, but Blake classed them with the Upper Kimeridge. The stratigraphy immediately to the east of Hen Cliff is somewhat dubious, and until this is made perfectly clear we cannot be said quite to understand the position of the beds, estimated at 150 feet, which occupy the cliffs of Kimeridge Bay, and whose harder portions constitute the ledges. In his second paper ("Portland Rocks of England") Blake had no hesitation in referring these to the Lower Kimeridge.

Unquestionably the lowest beds seen on this coast, including the Bench-rock, forming the Broad Bench on which the party stood during the explanations given by the Director, must be well within the Lower Kimeridge. This is proved by the presence of *Am. alternans* (in abundance) and several characteristic Lower Kimeridge ammonites; whilst immediately below the Bench rock, and in the shales of Hobarrow Bay, exposed at low tide, may be found nearly all the characteristic ammonites of the Virgulian horizon, e.g., *Am. eudoxus* and *Am. longispinus*, together with *Exogyra virgula* in plenty, and an abundant Lamellibranch fauna.

2. *Comparison of the beds on either side of the anticlinal.*—The very sharp dip on the north-west side seems to make the beds of Kimeridge Clay go into a very small space. We are probably dealing with at least 800 feet of beds as developed on the south-east limb of the anticlinal. Is there as great a thickness on the north-west side? Perhaps not. The coal-bed, for instance, seems to have shrunk from 2 ft. on the south-east, to 3 in. on the north-west, and the fact of its not being worked on the Brandy Bay side seems to accord with this attenuation. Cement stones have been picked up in Brandy Bay, and towards the top we get *Discina latissima* again, and the fossils of the Upper Kimeridge.

3. *The local stratigraphy.*—The attention of the party had already been drawn to the repeated faults on the west side of

Kimeridge Bay, where there was a succession of uplifts towards the north-west. This system of uplifts culminates in the Hobarrow Bay fault, presenting some curiously deceptive features, which a walk of a few hundred yards towards the north would enable the members to investigate at close quarters.

The party accordingly advanced along the almost level surface of the Bench-rock until close under the cliff, where they could easily perceive the dislocation, whereby the platform on which they were standing is lifted some fifty feet into the cliff on the north-west side. Owing to peculiar circumstances, which are best explained by reference to the accompanying section (Fig. 3), the throw of this very important fault had originally been estimated at only six feet.

The party now temporarily broke into two sections, the

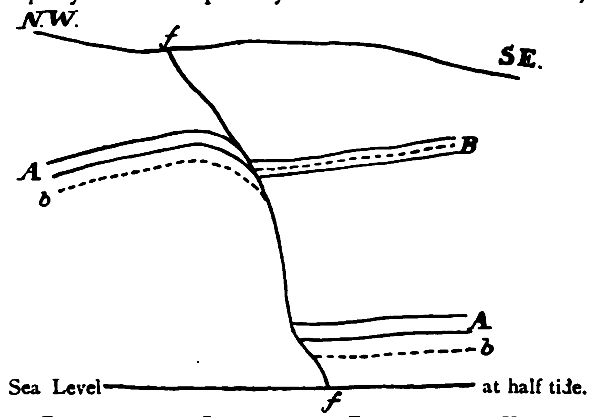


FIG. 3.—DIAGRAMMATIC SECTION OF A FAULT IN THE KIMERIDGE CLAY, HOBARROW BAY.

A. The "Bench-rock," an impure and ferruginous cement stone, such as forms the Kimeridge ledges hereabouts. This one constitutes the Broad Bench, a rocky platform between Kimeridge and Hobarrow Bays.
B. The "Double-rock," a hard band of similar composition higher in the series.
b. Shale full of Lower Kimeridge fossils, including *Exogyra virgula* in great numbers, *Ammonites alternans*, etc.
f. Fault with downthrow to S.E., estimated at 45 feet by Mr. Strahan.

more adventurous accompanying the President along the rocky shore, at the foot of these grand cliffs, towards the corner at Brandy Bay; whilst those disposed for a less arduous walk followed the Director, who was bent upon regaining the edge of the cliff. This latter section had thus the advantage of an easy walk on the greensward, with steady rise towards the crest above Brandy Bay, in alignment with the precipice of Gad Cliff (Fig. 4), where they were ultimately joined by the other section, who surmounted the very steep slopes with the ardour of practised mountaineers.

The crest of Gad Cliff was now followed all the way to "Pondfield Cove," at Worbarrow. Though not so lofty as Swire Head or St. Alban's Head, this is certainly the most striking precipice in the Isle of Purbeck. Its geological features are shown in Fig. 4, where the main mass of the precipice is seen to consist of the Cherty beds of the Upper Portland. But on following the edge of the cliff, from the highest point, in its rapid descent towards Pondfield Cove, a considerable thickness of Lower Purbecks must be added to the cliff section, and this is further proved by the occurrence of fossil trees from the Dirt-bed which have been seen on the talus.

There is an excellent section of the Purbeck and Portland

FIG. 4.—SECTION AT GAD CLIFF, ISLE OF PURBECK.
H. B. Woodward.

3. Upper Portland. Cherty Stone.
2. Lower Portland.
1. Kimeridge Clay.

beds to be seen in Pondfield Cove (east side of Worbarrow Knob). Only the Middle and Lower Purbecks are here visible. The general result is nearly the same as at Bacon Hole (Fig. 5), on the opposite side of Worbarrow Bay. There are some interesting features in connection with the Portland Stone of this locality. The "shrimp-bed," which forms the top of the series in the Isle of Purbeck (except at Tilly Whim), is here well-developed. It is full of badly-preserved fossils, mostly bivalves, *Pleuromya tellina*, *Cardium dissimile*, *Trigonia gibbosa*, etc., in a hard, white,

creamy rock. The *Perna*-bed is indicated in its proper place with some large ammonites (*Am. giganteus*?). There is no development of the Building-stone series, so that the Cherty series which forms the main mass of the Portland Stone may be said to be in almost direct contact with the *Perna*-bed. It seems probable that throughout the whole of the long exposure of Gad Cliff the Portland Building-stone series is unrepresented.

That invaluable horizon, the Middle Purbeck cinder-bed, was easily found in Pondfield Cove, and a few feet below it Mr. Louis was fortunate enough to discover the chert with remains of *Chara* in position. This was felt to be particularly satisfactory, as the specimens obtained from the old pit above Tilly Whim were not *in situ*, though the evidence there was in favour of their having come from the horizon in which *Chara* was found here.

The party drove back to Swanage by way of Corfe.

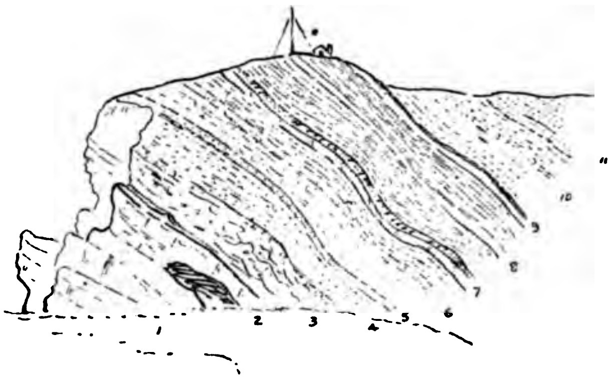


FIG. 5.—SECTION OF CLIFF AT BACON HOLE, MUPE BAY.
H. B. Woodward.

11. Wealden Beds.
10. Shales, etc., with Purbeck Marble. } Upper Purbeck.
9. *Unio*-Beds and Broken Shell Limestone. }
8. Corbula Beds, etc., shales and limestones. } Middle Purbeck.
7. Cinder Bed—Hard Limestone—Flint Bed. }
6. Marls with conspicuous band of harder white marl. } Lower Purbeck.
5. Sandy and honey-combed bands : top of Hard Cockle Beds. }
4. Cypris Freestone, etc. }
3. Broken Beds merging downwards into Soft Cap. }
2. Caps with intermediate Dirt-bed. }
1. Portland Stone with *Ammonites giganteus*, etc. }

Tuesday, April 7th.—Mr. Mansel and Mr. Hudleston were the Directors. The members drove from Swanage to Blashinwell Farm, a little N.W. of Kingston, to inspect sections in the patch of calcareous tufa marked on the new edition of the Geological Map. They were there met by the Rev. Owen L. Mansel, who pointed out the principal features of the deposit.

The following is the substance of Mr. Mansel's remarks:

"The Tufa bed of Blashinwell, evidently of Neolithic date, lies on the Weald clay which occupies the central valley of the Isle of Purbeck. It is about eight feet thick, and covers an area of five or six acres, conforming to the contour of the land which here gently slopes towards the brook which runs through the valley to Corfe Castle.

"Viewed from a short distance it has the appearance of chalk, but a closer inspection reveals its true nature and geological age, both from its internal structure, and quasi-fossil contents.

"The formation is unstratified, and is such as would be produced by the deposition of mineral substances from water highly charged with lime. The particles of calcareous matter of which the mass is composed very generally assume a spheroidal and cylindrical form, varying from the size of small grains to that of a pea, the organic substances which they envelop being in many instances well preserved. Imbedded in the tufa are numerous land-shells of species usually found in woods, which, with the impressions of leaves of oak, elm, hazel, etc., indicate a forest growth in the neighbourhood. The beech-feeding *Clausilia laminata* is stated by Mr. Mansel-Pleydell to occur in the deposit, but no remains of the beech itself have yet been discovered. That the spot was chosen as a settlement by a community of some race of primæval man during the formation of the tufa is evidenced by the presence of the shells of limpets, periwinkles, and some other edible marine molluscs, together with the bones of deer, ox, wild boar, etc., which are often split longitudinally, also fragments of charcoal and flint chips, all of which are found in considerable abundance, but no pottery. Mr. Clement Reid (in a most able and interesting paper which he read before the Dorset Field Club last December) draws the inference from the absence of the remains of the larger extinct mammalia, that the relics are those of Neolithic men, an opinion which appears to be borne out by the fact that the sea-shore was then, as now, within easy reach of the locality, which could not have been the case during the Palæolithic period if, as is, I believe, generally supposed, the land was much more elevated; and therefore the sea must have been at a greater distance, and probably inaccessible. But I cannot think that the conditions under which the remains are distributed throughout the deposit quite justify the description which Mr. Clement Reid has given of it, as a gigantic kitchen midden.

"There can be little doubt as to the origin of the deposit. It is known that the water of many springs, holding carbonic acid in solution, is enabled to dissolve the calcareous rocks over which it flows, and, when the acid is dissipated in the atmosphere, the mineral ingredients are thrown down in the form of tufa or travertin; from such a cause has this deposit originated. About

200 yards higher up on the slope on which it rests, a considerable stream of water issues from a spring in the Purbeck limestone, and still runs in the same direction as in ancient times, though it no longer deposits calcareous matter. Mr. C. Reid accounts for this by supposing that the petrifying process was arrested by the destruction of the forest which once flourished in the vicinity. I venture to suggest another explanation, viz., that the period of deposition coincided with a time when some subterraneous action had raised the temperature of the water to the condition of a thermal spring, which gradually cooled down. I am inclined to think that the period of formation of this deposit was of comparatively short duration; at all events, the tufa had ceased to be deposited, either from the cooling of the water, or the diversion of the course of the stream, or from some other cause, before the Roman occupation of this country, as the Romano-British remains found in the dark soil above are never coated with lime. A grave in the tufa, lined with slabs of Purbeck stone, and containing a skeleton in a sitting posture, has been recently exposed to view. The interment is apparently of very ancient date, but must, of course, have taken place after the formation of the tufa had ceased."

After inspecting the marl-pit at Blashinwell, the attention of the party was drawn to the position of the Burr-bed towards the base of the Upper Purbecks, and also to the spot whence the *Paludina*-marble was obtained for the new church at Kingston. A somewhat stiff pull up the hill brought the party to the church, where they were met by Mr. Hudleston, who conducted them for the remainder of the day. It is now about sixteen years since the Eldon family completed this church, at great cost, entirely out of materials quarried on the estate. The outside work is Burr stone, the same as was used for the outside work at Corfe Castle. The interior work is mainly of Portland stone from the London Doors quarry, with pillars of *Paludina*-marble, which wears well if protected from the weather. A few pillars on the outside present a somewhat rusty appearance, due, probably, to oxidation of the iron in a damp atmosphere.

A move was now made for the London Doors Quarry, showing the junction of Purbeck and Portland beds. Dealing with the latter only, the Director was able to exhibit specimens of the "shrimp-bed," containing some fragments of the little crustacean, and Mr. Wickes succeeded in finding a very satisfactory specimen, which he has presented to the Museum of Practical Geology. The underlying *Perna*-bed is here in its place, but it does not present such a "lumachelle" of oysters as at Tilly Whim. The Building-stone series, for which the quarry had been opened, is at present no longer visible, being buried under the rubbish of the higher beds.

From this place a stroll along the plateau enabled the party to

find a spot, just above Encombe House, sufficiently sheltered for lunch. When this had been discussed, a further stroll in a westerly direction brought them to the flat summit of Swire Head. As the physiography of this region had been very fully demonstrated by the Director, from this spot, fourteen years ago, he contented himself with reading extracts from his previous report.* Some slight modifications, he thought, might have to be made, in consequence of Mr. Strahan's results in the Weymouth district. Nevertheless, the main features of the grand sweep of country, which the members saw before them, were due to stratigraphical and denuding agencies, which had operated in that area since later Miocene times, including even the excavation of the Weymouth anticlinal, notwithstanding some difference in the age of the faults. A vote of thanks to the Directors was proposed by the President and carried by acclamation.

The major portion of the party, including the President, then regained the carriages and returned at once to Corfe Castle, where refreshments had been ordered. Rather over a dozen followed the Director, in accordance with the programme, to the coast section below Little Kimeridge. This was the first time that the Association had succeeded in reaching the excavations for Kimeridge Coal, which are carried out in the face of the cliff. Particulars with regard to Kimeridge Coal and the associated bituminous shales are given in the previous report. The industry seems at present to be languishing, although there are piles of the material collected in one or two places. Pyritized specimens of *Ammonites pectinatus*, Phil., are abundant in the Kimeridge Coal—a fact not hitherto noticed, though very important by way of correlation. It serves to show that the Kimeridge Coal is on the horizon of the well-known and richly fossiliferous "Lower Portland Sands" of Swindon. Consequently we have no difficulty in believing that the Kimeridge Clay of Chapman's Pool is on the horizon of the Hartwell and Swindon clays, at least approximately.

This section of the party had a somewhat difficult scramble down the face of the cliff to the shore, where the usual fossils of the Upper Kimeridge were duly identified. Just before reaching the corner at Hen Cliff, they came upon the fossiliferous horizon mentioned by Blake in connection with the so-called *Am. Thurmanni*. Here, on the very same slab of shale, and in the midst of other fossils, were found *Discina latissima* and *Exogyra virgula*—a more complete inosculation of Upper and Lower Kimeridge could hardly be imagined.

There was some difficulty in whipping in the stragglers, and when at length all were collected in the large brake awaiting this party on the crest above the village of Kimeridge, there were grave doubts as to whether the 5.10 p.m. train from Corfe Castle to Waterloo could be caught. These doubts, however, proved

* *Record of Excursions*, p. 325.

SECTION ON THE EAST SIDE OF STAIR HOLE.
(*From a Photograph by* H. PRESTON, F.G.S.)

To face p. 323.

unfounded; and the two sections of the party once more united at the railway station, whence the majority proceeded to London, as indicated in the programme.

APPENDIX. BY MR. LEIGHTON.

During the excursion some of the members visited Lulworth, under the direction of Mr. T. Leighton, F.G.S.

On the arrival of the party at the look-out above the western headland, the Director gave a brief description of the section seen on the east side of Lulworth Cove. The party then proceeded to Stair Hole and inspected the celebrated section of which the details are shown in Fig. 6. A photograph was taken by Mr. H. Preston, which is reproduced as Plate XII. The Director then

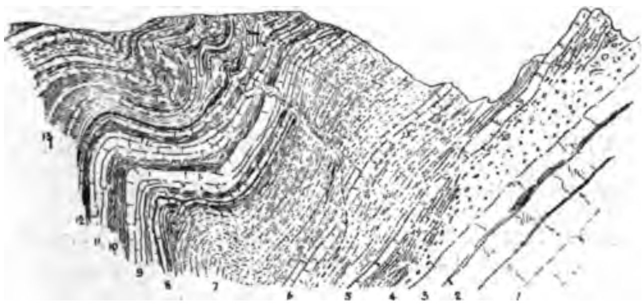


FIG. 6.—DIAGRAM-SECTION OF PART OF STAIR HOLE, LULWORTH, DORSET.—*H. B. Woodward.*

Beds 9 to 13 Middle Purbeck.
Beds 2 to 8 Lower Purbeck.
Bed 1 Portland Stone.

Figs. 1, 4, 5, and 6 are reproduced from H. B. Woodward's *Jurassic Rocks of Britain*, vol. v, with the kind permission of the Director-General of H.M. Geological Survey.

made some remarks on Mr. Strahan's recent paper on Overthrusts of Tertiary Date in Dorset,* and reminded the members that it was in the "Proceedings" of the Association that attention had been first called by Mr. Hudleston to the fact that the folds of the district had taken place at two periods. The Director believed that the series of infra-Cretaceous movements was connected with the unconformity between the Jurassic and Cretaceous rocks, one of the most familiar features to students of the geology of the south-east of England.

After a careful examination of the beds exposed on the shore

* *Quart. Journ. Geol. Soc.*, vol. li, p. 549.

at the eastern side of Lulworth Cove, the party returned to Swanage.

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VISIT TO THE ZOOLOGICAL GARDENS.

SATURDAY, APRIL 18TH, 1896.

Directors: THE PRESIDENT (E. T. NEWTON, F.R.S.) *and* F. E. BEDDARD, F.R.S., F.Z.S.

(*Report by* THE PRESIDENT *and* R. S. HERRIES.)

BY kind permission of the Council of the Zoological Society, members of the Association were admitted to the Gardens free of charge, and assembled at the Elephant House, where Mr. Beddard, who had, at a short notice, kindly taken the place of Dr. Sclater as Director, gave an account of the recent species of Elephant and Rhinoceros. He regretted that the Society had now representatives of three species of Rhinoceros only, namely, the Indian (*R. unicornis*), the Sumatran (*R. Sumatrensis*), and the Hairy-eared (*R. lasiotis*); the first having one, and the others two horns. The other living species are the Javan (*R. Sondaicus*) with one horn, and the black and white African two-horned forms (*R. bicornis* and *R. simus*). Lately, what is considered by some to be a distinct species has been discovered in Africa, thus making six—or, at the most, seven—living species. It was explained that the Rhinoceros belonged to the *Perissodactyl*, or odd-toed section of the order of *Ungulata*, and its nearest allies in consequence were the Tapir, and, curious though it might seem, the Horse.

As to Elephants, Mr. Beddard said the Society had specimens of both the living representatives of the group, the Asiatic

and African (*Elephas Indicus* and *E. Africanus*). Some distinguish the Elephant of Sumatra as a species distinct from the Asiatic Elephant under the name of *Elephas Sumatrensis*.

The differences between the Asiatic and African Elephants are so marked as to be almost generic. The dentition is different, the teeth of the African elephant having the worn edges of the enamel lozenge-shaped, and much more open than those of the Asiatic form, which more nearly resemble those of the Mammoth. The most noticeable external points of difference are the larger ears and rounded skull of the African Elephant, and the fact that it has two finger-like processes at the end of its trunk, one above and one below, while the Asiatic Elephant has only the upper one. Referring to the small Asiatic Elephant recently acquired, and then before them, Mr. Beddard said that it was two years old, and he mentioned a well-ascertained case of an elephant that was still living, a few years ago, at the age of 166 years.

The President then spoke of the fossil forms of Rhinoceros, beginning with the Woolly Rhinoceros (*R. antiquitatis*), so well known as the form which has been found frozen in the Arctic regions, and still retaining the skin and hair. This creature is a characteristic Pleistocene animal, being found in cave-deposits, brick-earths, and deposits of similar age both in Britain and on the continent, as well as in Asia. The upper molar teeth of this species are peculiar, in that the median valley is so divided across, that when worn it shows a distinct "island" of enamel. A similar form of tooth is found in the living Indian *R. unicornis*, and in the African *R. simus*. *Rhinoceros leptorhinus*, another Pleistocene species, is of more slender build, and its molar teeth do not show the "island" of enamel, in this respect resembling the living Javan, *R. Sondaicus*.

Rhinoceros megarhinus had teeth very similar to those of *R. leptorhinus*; but, although occurring in Lower Pleistocene beds, it also extends further back in time, one tooth having been found in the Norfolk Forest Bed, and it is known on the continent also in beds of Pliocene age.

After alluding to the smaller form known as *Rhinoceros etruscus*, which is commonly found in the Norfolk Forest Bed, and in Pliocene deposits in Italy, France, and Spain, and to the few teeth of *R. incisivus* and *R. Schleiermacheri*, found in our own Red Crag, and in beds of similar age in Europe, mention was made of the numerous fossil species of this genus found in the Pliocene of India, of the *R. minutus*, with two horns placed transversely, from the European Miocene, and of the hornless forms, resembling *R. incisivus*, which have been found in North America.

Passing to the fossil Elephants, the Mammoth (*E. primigenius*) was first noticed, it having been found, like the Woolly Rhinoceros, in a very perfect state, frozen in the tundras of Siberia,

and from those remains we know that it was provided with a thick covering of woolly hair. The Mammoth was a Pleistocene animal; indeed, notwithstanding that its remains, or something very like it, have been found in the Norfolk Forest Bed, it may be called the characteristic Pleistocene Mammal. The teeth of the Mammoth, like those of all Elephants, are peculiar; there are no canine teeth, and the only incisors are the tusks of the upper jaw. There are six grinding teeth on each side in each jaw, but these are never all in place at the same time. They are formed at the back of the jaw and, growing forward, the later teeth press out the earlier ones in front of them. Each grinder is formed of a number of plates of enamel, enclosing dentine; these are held together and surrounded by the bony matter which is called cement. The number of plates varies in the different teeth, being few in the earlier teeth and more numerous in the later ones. They also vary in different species, the greatest number being found in the Mammoth, in which the hindermost tooth may have from eighteen to twenty-nine plates.

The reduction of the number of tooth-plates, and the lowering of their crowns in different species was then traced from the Mammoth through the *E. antiquus* (Pleistocene and Pliocene of England and the Continent), *E. meridionalis* (Pliocene, England and Europe), *E. planifrons*, *E. insignis*, and *E. Clifti* (all three Indian Pliocene), and thence to the *Mastodon Borsoni* (Pliocene, England and Europe), and *M. angustidens* (Miocene, Europe and Asia). Although this series of forms could not be said to be the line of descent of the Mammoth, yet it served to show how such a pig-like form of tooth as that of the *Mastodon angustidens*, or *arvernensis*, might by gradual modifications become changed little by little into the highly specialised grinder of the *Elephas primigenius*.

Hearty thanks were given to Dr. Sclater and to the Council of the Zoological Society for the privilege of meeting in their beautiful Gardens, and to Mr. F. E. Beddard for the interesting account which he had given of the living forms of Rhinoceros and Elephant. The party then dispersed to see the many objects of interest, Miss Gorilla, the new anthropoid ape, being one of the first to receive attention

EXCURSION TO HENDON.

SATURDAY, APRIL 25TH, 1896.

Director: H. HICKS, M.D., F.R.S., PRESIDENT OF THE GEOLOGICAL SOCIETY.

Excursion Secretary: W. P. D. STEBBING, F.G.S.

(*Report by* H. W. MONCKTON, F.L.S., F.G.S.)

THE party assembled at Hendon Station at about three o'clock in the afternoon, and walked to Hendon Grove, where they were

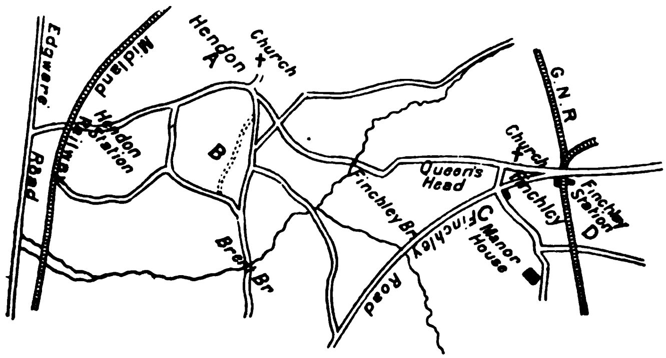

FIG. 1.—SKETCH-MAP OF NEIGHBOURHOOD OF HENDON.—*H. Hicks.*

A. Hendon Grove Pit. B. West View Pit. C. Manor Field Pit. D. Plowman's Brickfield.

received by the Director, and were most hospitably entertained at tea by Mrs. Hicks.

After tea the Director drew attention to some specimens from an excavation for a new sewer in the valley to the north of Hendon. Amongst them there was a fine tooth of a rhinoceros, and fragments of bones belonging to animals of that species. There were also a quantity of fragments of a tusk of a mammoth. These specimens were found in 1895, some five feet below the surface of the ground, and were overlain by a deposit of clay full of flint pebbles. The level of the locality is about 160 ft., O.D.

The Director then referred those present to his sketch-map of Hendon, published in the Quarterly Journal of the Geological Society for 1891*, and reminded the members that last time the

* Vol. xlvii, p. 584

Association visited Hendon he was able to show how much more extensive the gravel and drift deposits are round Hendon than is indicated in the Geological Survey Map. The hills are, in fact, not only capped but mantled by a covering of drift, usually down to the 200 feet contour line, and in places to a much lower level.

The Director added that the following seemed to be the succession in these drifts, beginning at the bottom :

1. A coarse gravel, often with large sarsens.
2. Sand and some gravel, well stratified;
3. Clay, often extremely like London clay, with a few stones; and
4. Irregular gravel patches (on the surface of the ground).

Now the interesting question arose whether we could connect the clay bed No. 3 with the clayey bed which spread so largely over the valley, and under which the rhinoceros and mammoth remains had been found. In answer to Mr. H. B. Woodward, who asked whether mammalian remains had been found on the

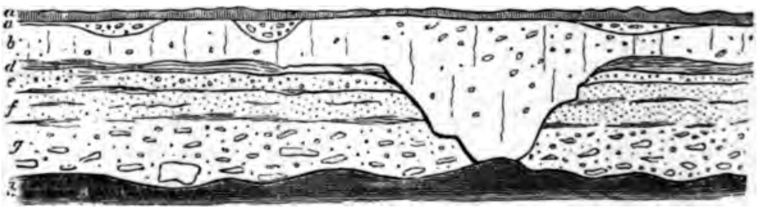

FIG. 2.—SECTION IN UPPER GRAVEL-PIT AT HENDON GROVE.—*H. Hicks.*

(About 35 feet in length.)

a. Surface soil.
a'. Gravelly soil (with flints) irregular.
b. Yellowish-brown clay, in places passing downwards through the underlying sands and gravels. 2 to 7 feet.
d. Loamy sand with ochreous bands. 1 foot.
e. Gravel. 1 foot.
f. Yellowish sand, sometimes showing current-bedding. 2 feet.
g. Ochreous gravel, with large pieces of sarsen-stone, rounded and subangular flints, chert, quartzite, quartz, ironstone, etc. 2 to 4 feet.
h. London clay, much disturbed, of a brown colour, and forming a very uneven floor under the glacial deposits.

plateau, the Director said he had only seen some fragments of elephant bones.

The party, forty-seven in number, then proceeded to a field where there were formerly workings for gravel—A in Fig. 1—and the Director had very kindly caused a small opening to be made, so that the members were able to form a fair idea of the nature of the deposit (Fig. 2).

The writer had the advantage of visiting it in company with Dr. Hicks, on February 12th, 1890, and the clay bed (*b*) was then clearly seen cutting down into the gravel below. Under the clay were alternations of stratified sand and gravel.

Another section, lower down the hill, was also visited by the party, and showed yellow sand, false bedded, with a few thin layers of pebbles and subangular flints.

The Director said that, though he did not, on that occasion, wish to bring forward any theories, he could not help saying that he failed to see how these well-stratified deposits, especially the brown clay, could have been deposited in anything but quiet water, and he hinted at a possible lake.

Professor Bonney thought that, unless there were very large streams of water entering the lake, there would not be enough power to move the materials of which the gravels are composed.

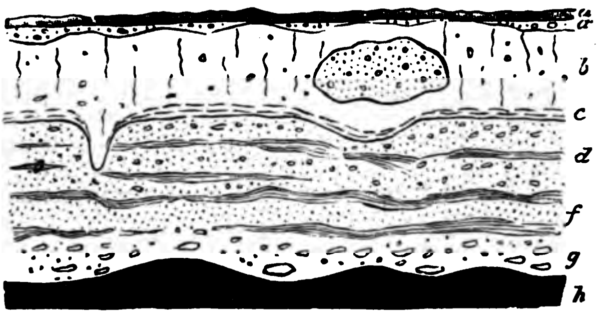

FIG. 3.—SECTION IN WEST VIEW GRAVEL-PIT, HENDON.—*H. Hicks.*
(About 20 feet in length.)

a. Surface soil.
a'. Gravelly soil.
b. Brown clay, with a few flints, patches of gravel, and in places much "race." 6 feet.
c. Laminated sandy clay. 6 inches.
d. Grey sandy gravel.
f. Yellowish sand with seams of clay. 2 feet.
g. Gravel with angular masses of sarsenstone, subangular flints and flint pebbles, chert, quartzite, etc. 2 to 3 feet.
h. London clay.

When an ordinary stream entered a lake its velocity was quickly checked, and the coarser materials formed deltas of very limited extent.

Leaving Hendon Grove, the party proceeded, by way of Hendon Church and a disused working close by, to the West View Pit (B, Fig. 1).

This pit for a long time gave a very fine section of the gravels of Hendon. It is about 280 feet, O.D. The following details were recorded by the writer in 1890.

The gravel is very largely composed of flint pebbles, no doubt from Eocene pebble beds. It contained many subangular flints, and a few flints which had been very little rolled or water-worn. A few pebbles of quartz occur; the largest noted measured 3 × 2 inches, and there were several over an inch in longest diameter. There was a good deal of Lower Greensand chert, and some blocks of sarsen-stone. One measured 16 inches × 15 inches, and another 17 inches × 16 inches. There were also smaller fragments of a white quartzite, most of which were probably, like the sarsens, of Tertiary age. The whole of this material might have been derived from Eocene Beds and Southern Drift Gravel.

Dr. Hinde remarked on the pebbles and fragments of Lower Greensand chert found at Hendon, "that the kind of rock is abundant in the Lower Greensand south of the Thames, whereas no one knows of its occurrence to the north." This question as to the origin of the chert is one of interest.

Professor Prestwich has recorded the occurrence of Lower Greensand chert in his Westleton Shingle, at Westleton, in Suffolk; from the gravel at Bacton, which he correlates with the Westleton Shingle, but which is classed with the Forest Bed by Mr. Clement Reid,* and from gravel at Jacks Hill, Epping, Barnet, etc. The writer has also found chert and ragstone, which he has no doubt is derived from the Lower Greensand, in numerous gravel sections north of the Thames.

Professor Prestwich considers that this chert, etc., was probably derived from the Lower Greensand of Kent,† and the writer has not been able to find any stone of a similar character in the Lower Greensand north of the Thames. Dr. Hicks is, however, inclined to think that similar beds may at one time have been exposed to the north.‡

Leaving the West View pit, the members descended the hill, and by the kind permission of the proprietor (W. H. Fordham, Esq.), they passed through the gardens of Holly Mount, and visited a gravel-working in a field about a quarter of a mile east of Hendon Station.§

The level is not much above that of the Midland Railway. The gravel is a good deal bleached, and is mainly composed of flint pebbles. There is some Lower Greensand chert, and also small quartz pebbles.

On the motion of the President, a very cordial vote of thanks was given to the Director and Mrs. Hicks for their hospitality, and to the Director for a particularly pleasant and interesting

* See *Quart. Journ. Geol. Soc.*, vol. xlvi (1890), p. 104, and Clement Reid's *Geology of Cromer*, p. 39.

† *Quart. Journ. Geol. Soc.*, vol. xlvi (1890), p. 97.

‡ *Quart. Journ. Geol. Soc.*, vol. xlvii (1891), p. 584.

§ Holly Mount is named The Hawes on the map, *Quart. Journ. Geol. Soc.*, vol. xlvii (1891), p. 584.

excursion. The members returned to town by the 6.31 train from Hendon.

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EXCURSION TO DORKING AND LEITH HILL.

SATURDAY, MAY 2ND, 1896.

Director: THOS. LEIGHTON, F.G.S.

Excursion Secretary: W. P. D. STEBBING, F.G.S.

(*Report by* THE DIRECTOR.)

THE object of this excursion was to study the lithological changes in the so-called Hythe Beds of the Lower Greensand from south to north, between Leith Hill and Dorking, as set forth by the Director in a paper printed by the Geological Society (see *References*, 1895). The occasion is rendered memorable by the discovery of the Bargate Stone in Punch-Bowl Lane, Dorking, underneath the Pepper and Salt Sands of the same series, which were utilised by the Director in the same paper to connect the Bargate Beds of Wotton with the Nutfield beds of Reigate. The outcrop of Bargate Stone now first recorded lies within the area stated by the Director to be occupied by that series; it is three miles east of any previous record of beds of Bargate Stone, and five miles west of Bell Street, Reigate, where the Bargate Sands are next seen approximately at the same horizon above the Atherfield Clay. The discovery is important in that it proves the value of the Sands, which are more frequently exposed, for the purposes of mapping. This is not by any means the first occasion upon which important facts have been brought to light on the excursions of the Association.

A party of thirty assembled at the Dorking station (L.B. & S.C.R.), and walked to Punch-Bowl Lane, where, after briefly pointing out the geological features of the district, the Director called attention to the section of Bargate Sands with the usual lydite and other pebbles underlying typical Folkestone Sands.

The Bargate Sands here correspond exactly to "Bargate Beds" (*a*) of the section on page 104, *op. cit.* Further along the lane, to the south, the Bargate Stone was seen as stated above, cropping out in the low bank on the roadside and in the gutter. The outcrop is immediately under the Sands, some dozen paces south, but future visitors are recommended to examine the locality in the early spring, when the bank is free from vegetation and dead leaves. The stone is quite of typical character, a hard calcareous grit, here rather fine in texture, the cementing material slightly crystalline, with fragmentary fossils and needle-shaped sponge spicules. Proceeding south, the sandy nature of the beds below the Bargates was pointed out, overlain by, in several places, drift consisting of chert and Bargate Pebbles. This Drift, the Director pointed out, must have been brought by the Mole from the south, and is derived from beds originally laid down over Holmwood Common to the east of Leith Hill. At the outcrop of the Atherfield Clay at the southern end of the cutting through the Lower Greensand escarpment, the Director pointed out how the horizon of the clay could be mapped without a section by the moisture at the roadside.

From this place the party drove to Chart Lane to the west, where a similar, but better, section of the sandy area of the Lower Greensand was seen. Over the Atherfield Clay are iron sands (Local Group 4), then the clayey sands with phosphatic nodules into which the chert beds of Leith Hill pass northwards, then, although not shown in this lane, the Bargate Beds followed by the Folkestone Sands. The high-level drift of chert and Bargate pebbles was well seen in this lane. The party then drove to Coast Hill, Wotton, and examined, for the sake of comparison, the well-known section of Bargate Stone at the Rookery fault. South-west of the fault the Leith Hill cherts are seen, 60 ft. thick. The Director stated that the appearance of chert so far north on this horizon was unusual; east and west these beds were represented by clayey sands. It was also pointed out that this section showed slightly intermediate conditions, some false-bedding appearing, and sand forming the mass of the rock, although there was plenty of chert with it. In its passage south even this sandy chert (the upper division or northern facies of the Leith Hill beds) became more of a sponge rock, the quantity of chert in the beds increasing southwards. The Director considered that the presence of the chert series so far north at this spot pointed to quieter conditions having obtained here, whilst the unusual false-bedding and greater proportion of sand, in connection with other known facts, showed more littoral conditions than in the beds on the same horizon further south, which are not false-bedded, and contain more chert. At Coast Hill on this horizon, water, quiet enough to support sponge life, appeared to have approached nearer to the shore.

After a halt of a few minutes for lunch, the party drove to the hollow lane south of Wotton village, where the vehicles were dismissed, the remainder of the journey being made on foot. The section in this hollow lane shows the same beds as at Coast Hill, but the succession is not complicated by a fault as at the latter locality. Walking southwards, the sandy cherts are first seen very much as above described at Coast Hill; the junction-bed (ironstone and sandy chert) ushers in the overlying Bargates, which consist of two divisions, below (*b*) Calcareous grit beds, sometimes hardened into stone, sometimes loose sands, followed by (*a*) Pepper-and-salt sands. All these beds are described in detail on page 104 of the paper referred to, and all are well shown in this section. The normal dip of all these beds is to the south, but Dr. Hinde called attention to the dip to north, seen in the chert series in certain places in this lane. The Director stated that that was a local dip only, and that he had called attention to it, and explained it, in his report on the Excursion to Abinger, which gave a full account of the physical geology of the district. The party then entered the woodlands that cover the upper dip-slope of Leith Hill, and in a new section on the west side of Abinger Bottom, on the footpath leading down S.S.E at 12 chains south of the extreme butt of the Rifle Range, examined the junction of the upper division (northern facies) and lower division (southern facies) of the Leith Hill chert series. The upper beds, the sandy chert beds, are as already described, but with more chert and less sand; only one bed of the lower division is shown in this pit, the bed of massive greensand with occasional cavities with sponge spicules. In many sections this bed appears to mark an abrupt change of conditions; it belongs, however, to a series of massive rocks, never false-bedded, containing thick beds of brown chert, still, however, with thin, sandy cherts and sandstones in places. In this immediate neighbourhood this massive greensand-bed is so constant below the sandy chert series, that a casual observer would be excused in mistaking it for a definite horizon; to the east, however, and south, particularly at Coldharbour, similar rock is found in more than one bed, and certainly *not* at the top of the series. The next pit visited was that on the opposite (east) side of Abinger Bottom, which the Excursion in 1893 failed to attain. This section is described in the report of that Excursion; the beds are the same as those just described on the west side of the Bottom. The Director here stated that the working of this comparatively new pit had ceased since his paper was written. During the last five years a change had taken place upon Leith Hill in the method of obtaining road metal, for which there was a considerable demand. The old deep quarries were abandoned because it was found cheaper to scratch up and sift the partially disintegrated chert immediately below the turf, the labour erstwhile performed by the

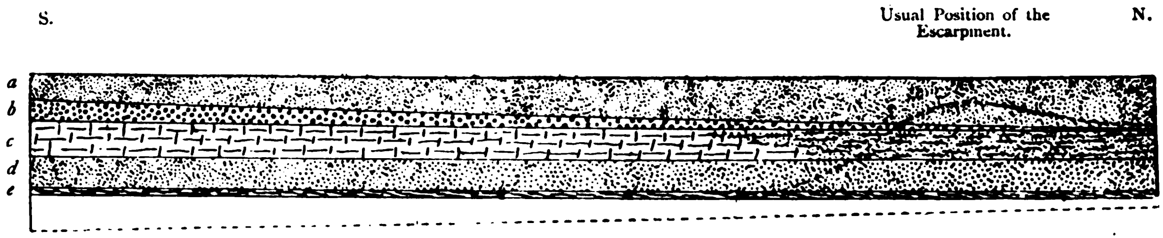

DIAGRAM TO ILLUSTRATE THE DEPOSITION OF THE LOWER GREENSAND IN EAST SURREY.—*T. Leighton.*

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a Folkestone Sands.
b Bargate Beds.
c Chert Beds in the south (Local Group No. 2) passing northward into clayey Sands (Local Group No. 3).
d Iron Sands (Local Group No. 4).
e Atherfield Clay.

"professional geologist" being now contributed by the "geological agent" known as "surface action." On the walk to the tower at the top of the hill a large number of these surface scratchings were examined. This economical change is greatly to be deplored from the geologist's point of view, because the old deep sections are rapidly weathering down.

After tea at the tower the party walked to Cockshot Hollow, and examined, below the chert series, the iron sands (Local Group 4), which everywhere in Surrey overlie the Atherfield Clay. Upon re-ascending to the path to Coldharbour the Director called attention to the outcrop of the lower Leith Hill beds, with thick beds of chert, etc., in the dry torrent bed up which the footpath courses. After passing through numerous surface workings, all of which save one, the Director stated, had been started since he commenced to work in the district, the party arrived at the now disused quarry above Coldharbour, which, the Director further stated, had been abandoned since his paper was written. The once splendid section has frequently been visited by the Association in the past; it is mentioned by Drew (Topley, *Weald Memoir*), and the general description of the lower Leith Hill beds, on page 104 of the Director's paper referred to, is taken from this quarry. The section is now much obscured by scree; the regular beds of hard rock still stand out, however, on the northern face, and in the centre of the quarry a slipped mass, almost entirely of solid chert, still stands out, clearly bearing evidence to what has been. Fragments, consisting of masses of sponge spicules (highly weathered chert), and specimens of the other rocks, can be obtained from the fallen *débris*. This is a typical section of the beds which, the Director maintains, bear evidence, (1) in themselves from their appearance, (2) from the thick sponge beds, (3) from absence of false stratification, (4) from the absence of pebble beds, and (5) from the much smaller proportion of sand interbedded with the cherts as sandy-cherts, of having been laid down in deeper water, or further from the shore, than the overlying sandy cherts which thicken to 60 feet at Coast Hill, or than the false-bedded clayey sands into which they pass north-eastwards and north-westwards. It should be noticed that the iron-sands (Local Group 4) may be seen immediately below the Coldharbour Quarry.

The examination of this section closed the geological work of the day, the party returning to town from Holmwood Station.

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EXCURSION TO CHINGFORD MUSEUM AND EPPING FOREST.

SATURDAY, MAY 9TH, 1896.

Director: T. V. HOLMES, F.G.S.

Excursion Secretary: W. P. D. STEBBING, F.G.S.

(*Report by* THE DIRECTOR.)

ON arriving at Chingford Railway Station, the party turned eastward to the Chingford Museum at Queen Elizabeth's Hunting Lodge, less than half-a-mile away. The Museum building is an ancient edifice of the Tudor period. On ascending the broad stairs the walls are seen to be largely covered by geological and other maps, and by prints and documents illustrating the past or present of the Forest district. In the large upper chamber, once the banquet-room, the chief part of the collection is placed; and here the party was met by Mr. W. Cole, curator of the Museum and secretary of the Essex Field Club.

The Director then remarked that as this was the first visit of the Geologists' Association to Epping Forest, he would offer a few general remarks on that district. The perambulation of 1641 showed that Epping Forest of that date consisted of 60,000 acres. But this gives the whole area under Forest laws, not the amount of waste, uncultivated land which formed but a small proportion of the total space included in the Forest. Passing over many details, for which the reader must be referred to Mr. Buxton's excellent *Guide*, it may be noted that in 1850, owing to the policy then pursued by the Commissioners of Woods and Forests of stimulating enclosures, the Forest consisted of but 6,000 acres. Between 1850 and 1870 half this area was enclosed and partly built upon. But during the last-mentioned period a new spirit had arisen with regard to the proper treatment of open spaces, as shown by the formation of the Commons Preservation Society, which included John Stuart Mill, Professor Fawcett, Miss

Octavia Hill, and other enlightened and influential persons. At last, in 1871, the Corporation of London, as commoners of Epping Forest, took steps which finally led to 5,542 acres being for ever preserved for public recreation.

The Forest is now under the charge of the Corporation of London, as conservators, and is managed by a committee, consisting of twelve members of the Court of Common Council and four verderers, elected by the commoners. Order is kept by a superintendent and twelve keepers.

The Museum is intended to illustrate the geology, natural history, and archæology of the Epping Forest district, understanding by that term the area included in the perambulation of 1641. It is now, owing to the exertions of Mr. W. Cole and other gentlemen living in the district, a local museum of the Essex Field Club, existing under the sanction of the Corporation of London. It was opened to the public on November 2nd, 1895.

Mr. W. Cole said a few words on the contents of the Museum and their arrangement. And referring to the size of Epping Forest at the present day, as compared with that of 1641, he said that his researches had convinced him that the area of waste and uncultivated ground had not diminished very materially since the time of Charles I., though the district nominally forest had been much reduced.

Leaving the Museum, the party inspected a gravel pit close by, in one of three small patches shown on the map of the Geological Survey as existing on the western flank of the valley in which Connaught Water lies, and coloured as river deposits. The patch close to the Museum appears to be from 180 to 190ft. above Ordnance Datum. Then, turning westward, they crossed Chingford Plain, and passing through a corner of Hawk Wood, entered a field in the highest part of which is an obelisk, 11 miles due north of Greenwich Observatory. From this point, which is just 300ft. above sea-level, a fine and extensive view was obtained; Shooters Hill standing out clearly about 12 miles S.S.E. A few yards from the obelisk is a pit in the upper beds of the London Clay, which are hereabouts more sandy than the main mass of that formation, and have been largely used for brickmaking. We were indebted to Mr. Jones, the owner of the brickyard and the adjacent land, for permission to visit this pit.

The party then proceeded in a northerly direction through Hawk Wood and Bury Wood, and across Ludgate Plain and Fairmead Bottom to Hill Wood, north of Fairmead Lodge, where the trees are chiefly beeches of much finer growth than the pollard oaks and hornbeams of the woods southward. Everywhere, indeed, in the higher parts of the forest, where sand and gravel cap the London Clay, beeches tend to predominate. High Beech, however, is, in the opinion of the Director

properly High *Beach*, because there the surface attains at one spot the unusual height of 370ft., and consists of an outlying patch of Bagshot Sand capped by gravel belonging to the Westleton Beds of Professor Prestwich. This Westleton gravel is the highest in point of altitude above the sea level, and the oldest in date of the gravel patches of Epping Forest. For Professor Prestwich's important paper on the Westleton Beds, see the *Quarterly Journal of the Geological Society* for 1890, pp. 84-181. The underlying Bagshot Sands are not at present exposed, but were seen by the present writer in 1887, when inspecting the excavation on the site of the reservoir at High Beach, in the company of Professor Meldola, Mr. H. B. Woodward, and Mr. W. Cole. (See *Essex Naturalist*, vol. i, p. 107). The section was about 60 yards long. At one end it consisted of about 7ft. of greenish-yellow Bagshot Sand, covered by 2ft. of gravel. At the other the Bagshot Sand had entirely disappeared, and the section consisted wholly of gravel towards the base, and clay, with scarcely any pebbles, in the uppermost 5 or 6ft. The junction between the two formations was highly irregular.

The view from High Beach towards the west, which included Waltham Abbey in the valley of the Lea, was much admired, and the party partook of tea at the King's Oak Hotel, High Beach. After tea a gravel-pit, a few yards away northward, which very recently displayed a good section of Westleton gravel, was found to be almost filled with sifted material and with water. It may be useful to persons visiting the Forest, with a view of inspecting the Westleton Beds there, to state that sections in them vary greatly from time to time, but that some may usually be seen close to Earl's Path, a road from Loughton towards High Beach, and at Jack's Hill near the "Wake Arms," N.E. of High Beach. Professor Prestwich, in the paper already mentioned, gives the approximate composition in a pit near the "Wake Arms" as:

1. Flint pebbles	50 per cent.
2. White quartz pebbles	15 "
3. Subangular fragments of flint ...	20 "
4. Subangular fragments of chert and ragstone	10 "
5. Pebbles of Lydian stone, etc. ...	5 "
	100

The full thickness of the London Clay in Epping Forest could only be ascertained by a boring at High Beach, where it is covered by the conformable Bagshot Beds. Judging from the results of the deep boring at Loughton Railway Station (see Whitaker's *Geology of London and of Part of the Thames Valley*, vol. ii, p. 26), and from another at Holly House, Chingford, the

details of which were kindly given me by Mr. T. Hay Wilson, I should estimate the thickness of the London Clay at High Beach at rather more than 400 ft.

Turning eastward from High Beach the party made their way to Loughton Camp. The other pre-historic camp of Epping Forest, known as Ambresbury Banks, has long been known to archæologists, but Loughton—or, as it is sometimes called, after its discoverer, "Cowper's" — Camp remained unknown till 1872, when it was accidentally discovered. It is about two miles south-west of Ambresbury Banks. Both camps have been carefully examined by the Essex Field Club, and an account of the exploration of the Loughton Camp may be seen in *Trans. Essex Field Club*, vol. iii, p. 214 (1884). Its position is one of much greater natural strength than that of Ambresbury Banks, and Mr. W. Cole, who had been a member of the exploration Committee, gave some account of it and of the interesting objects found. Many flint flakes, cores, and one implement were discovered, besides many fragments of rude, hand-made pottery, apparently of pre-Roman date. From the camp, looking southward, the party enjoyed a fine view over the woodland, and then made their way to Loughton Railway Station.

The Director has pleasure in acknowledging the services of Mr. W. Cole and of Mr. T. Hay Wilson in connection with this Excursion.

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EXCURSION TO CHIPPENHAM, CALNE, KELLAWAYS, AND CORSHAM.

WHITSUNTIDE, 1896.

Directors: REV. H. H. WINWOOD, M.A., F.G.S., and

H. B. WOODWARD, F.G.S.

Excursion Secretary: THOS. LEIGHTON, F.G.S.

(*Report by* THE DIRECTORS.)

I.—CHIPPENHAM AND KELLAWAYS.

BY H. B. WOODWARD.

LEAVING London by a mid-day train on Saturday, May 23rd, the members of the Association arrived at about 2 o'clock at Chippenham Station, where they were met by the Director. Luggage having been sent on to the Angel Hotel, and lunch having been

obtained at the railway station, the members were conducted to a small pit in the Cornbrash near by. The rock presented its usual characters of rubbly limestone, with *Avicula echinata* and other fossils.

Proceeding along the lane north-eastwards to Cocklebury Farm, the party ascended the slope which here and elsewhere to the south of Chippenham forms the escarpment of the Kellaways Beds. In the adjoining cuttings of the Great Western Railway and its branch to Calne the presence of sandy strata might here and there be observed, but as in the case of the South Cerney cutting visited by the Association in 1888,* the Kellaways Beds are seldom, if ever, to be detected at the surface in any natural outcrop, though their presence is indicated by a gentle escarpment, that rises about 50 feet. Proceeding across the meadows south of Rawlings and Peckingell Farms the members arrived at a deep water-course about half a mile below Kellaways Bridge on the right bank of the river Avon. Here beneath a thin alluvial deposit there was to be seen a thick bed of calcareous sandstone full of fossils, and underneath it brown and blue sandy and ochreous clays, with *Gryphæa bilobata*, exposed to a depth of 5 feet. This section, as remarked by the Director, was probably as good an exposure of the Kellaways Rock of Kellaways as any that had been opened in the past. By kind permission of Mr. Caleb Webber, of Upper Peckingell Farm, the members were allowed to scramble about the banks and break up the blocks of rock that were exposed, Mr. Webber himself having removed some fencing that prevented free access to the sections.

The Director mentioned that the fossils of "Calloway Bridge" had attracted the attention of Lhwyd, in 1699, and they had subsequently been described and figured by William Smith in his *Strata Identified by Organized Fossils*, and by the Rev. Joseph Townsend, in his geological work entitled *The Character of Moses*. The fact is that in old days the rock was quarried for road-metal, and the organic remains naturally came under the notice of travellers. Mr. William Cunnington (formerly of Devizes) had informed the Director that there was an old quarry "close to the road, on the north side, not far from the bridge, and the sides of the quarry were about 4 feet high." Mr. John Rhodes, Fossil Collector to the Geological Survey, had in 1887 found an old man who had informed him that the Kellaways Rock was worked on the Langley Burrell side of the Avon, about two or three hundred yards south of Kellaways Bridge. The rock was said to be about 6 feet thick, but no stone had been quarried for about thirty years, and the ground had long been levelled.

The Director pointed out that above the Cornbrash there was usually some 12 to 20 feet of ochreous and sandy clay, on top of

* *Proc. Geol. Assoc.*, vol. x, p. 157.

which there were bands of calcareous sandstone, sometimes in the form of doggers, sometimes in more persistent bands of shelly stone, and these alternated with clays and sands, attaining a thickness of 20 or 30 feet or more. In mass the Kellaways Beds thus formed an irregular basement-bed to the Oxford Clay. The rock-beds were hardly recognisable in Dorset, but they had been detected here and there in Somerset. The characteristic zonal fossil was *Ammonites calloviensis*. Specimens of this fossil were obtained by the members, who lost no time in setting to work at the tempting beds of rock that were exposed. In the end the following species were obtained by them, and (as in other instances) they were named by the President (Mr. E. T. Newton, F.R.S.):

Ammonites calloviensis.	*Pecten fibrosus.*
,, *Kœnigii.*	,, *lens.*
Belemnites Owenii.	*Placunopsis semistriata.*
Cerithium muricatum.	*Rhynchonella varians.*
Avicula inæquivalvis.	*Waldheimia obovata.*
Gryphæa bilobata.	,, ,, var. resembling *maxillata.*
Modiola sp.	
Myacites recurva.	*Waldheimia ornithocephala.*

The foot-bridge that here crosses (or should cross) the Avon was now found to be broken down, and marked: "Unsafe. By Order," one end of the wooden structure having fallen into the water, consequently the members had a rough scramble to get across. The passage was, however, successfully accomplished, and the party proceeded to Kellaways Bridge, and then visited a small gravel-pit on the western side. Here about 5 feet of gravel was exposed. It was formed chiefly of flat pebbles of local oolitic limestones, with a small percentage of flints. The Director remarked that remains of Mammoth had been recorded from the gravel at Christian Malford, while lower down the Avon valley other Pleistocene Mammalian remains had been found. Hence there was a chance of getting palæolithic implements, although none had as yet been discovered. Proceeding through Langley Burrell and down Pew Hill towards Chippenham, the party was conducted by Land's End and along the stony Gaston Lane over the Cornbrash to the Lowden Hill brickyard.

Here some of the species of fossils, previously obtained from the Kellaways Rock, such as *Myacites recurva*, were found in the sandy clays, and it was evident that the beds formed a portion of the Kellaways division, near the base of the Oxfordian formation. Some fine septaria were to be seen, but none of the hard beds of shelly stone that constitute the Kellaways Rock.

In the course of the evening the Director drew attention to some of the geologists associated with the district. He remarked that there were two reasons for their excursion: the district had

not before been visited by them, and it was a classical region for the geologist. One of the earliest Wiltshire writers who had given attention to geology was John Aubrey, F.R.S., who in his *Natural History of Wilts*, written between 1656 and 1691, observed, "I have often times wished for a mappe of England, coloured according to the colours of the earth; with markes of the fossiles and minerals." The same writer pointed out that the character of the "Indigenæ" varied according to the several sorts of earth in England, being respectively witty or dull, good or bad. North Wiltshire being "a dirty clayey country" the Indigenæ were said to be slow and dull, and heavy of spirit, melancholy, contemplative, and malicious; "by consequence whereof come more law suites out of North Wilts, at least double to the southern parts." Matters no doubt have changed since then! Coming to later times mention was made of Townsend and Wm. Smith, the latter of whom was consulted during the construction of the Wilts and Berks Canal. Sedgwick had in 1820 learnt some of his earlier field-lessons in a traverse from the Chalk hills near Marlborough and Devizes to the Oolitic valleys near Bath. Lonsdale had given us some of the first and best detailed sections of the Oolites. In those early days the Great Bath Road from London ran through Hungerford, Marlborough, Calne and Chippenham; and the coaches starting from the Angel Inn, St. Clement's, Strand, from Belle Sauvage, Ludgate Hill, from the Bolt-in-Tun, Fleet Street, or from the George and Blue Boar, Holborn, took some twelve hours in reaching Chippenham. The Great Western Railway had done much to add to the geological fame of Chippenham. Long trenches had been made alongside the railway near Christian Malford to obtain material for the embankments. These trenches, dug in the Oxford Clay, had yielded a remarkable series of fossils belonging to the zone of *Ammonites ornatus*. The Ammonites had been described by S. P. Pratt, who at one time resided at Bath. The species of *Belemnites* and *Belemnoteuthis* had been described and discussed by Owen and Mantell and Chaning Pearce; and the fishes had been described by Egerton. The Cephalopods in particular, were beautifully preserved, and in the case of the *Belemnoteuthis*, S. P. Woodward says, "In the fossil calamary of Chippenham, the shell is preserved along with the muscular mantle, fins, ink-bag, funnel, eyes and tentacles with their horny hooks; all the specimens were discovered, and developed with unexampled skill, by William Buy, of Sutton, near Chippenham."*

Buy, as the Director was informed by Mr. William Cunnington, was a carpenter and joiner at Sutton Benger. "When the Great Western Railway was cut through the district he was appointed as overlooker at the cuttings near Christian Malford. Here he was struck with the beauty and abundance of the splendid

* *Manual of the Mollusca*, 1851, p. 75.

Ammonites, etc. All were carefully dried, washed over with a solution to prevent their flaking off, and then cut accurately at the edges." The Director exhibited a specimen so shaped by Buy of *Ammonites Duncani* var. *spinosus*, also of the large *Belemnites Owenii.*

So arduously and so frequently did Buy labour among the clays of Christian Malford that when he had ceased his connection with the Great Western Railway, he continued to look upon the trenches as his own preserves. When, therefore, on one occasion he found a stranger digging at one of his favourite spots he at once ordered him off; but the stranger turned out to be Mr. Hugh Owen, chief cashier to the railway company!

Buy would never give an exact locality for his fossils, so many of them, whether from the Oxford Clay or Cornbrash, are labelled as from Chippenham, and that locality is therefore a noted one, as we may learn from the excellent Catalogue of British Fossils, by our old President, Prof. Morris.

II.—Yatton Keynell, Castle Combe, and Malmesbury. By H. B. Woodward.

In the afternoon of May 24th a number of the members started in a brake with four horses to Yatton Keynell. Here they alighted and were conducted by the Director to the picturesque old quarry described and figured by Prof. Hull in 1858.* The section showed the following strata:

			ft.	in.
	Forest Marble (Bradford Clay)	5. Flaggy oolitic limestone and clay	4	0
Great Oolite	Upper Division	4. Marly beds and shelly oolite . 6 ft. 0 in. to	7	0
	Lower Division	3. False-bedded oolite	6	0
		2. Irregular rubbly and ferruginous bed with Echini and Sponges	1	6
		1. False-bedded oolite	8	6

The beds had been examined in 1886 by the Rev. H. H. Winwood and the Director, and the latter had obtained a number of fossils, including *Terebratula coarctata*, although this species was not found *in situ*.†

Examples of this fossil were now discovered by Mr. Leighton and Mr. J. T. Day in bed No. 2, an horizon lower than that from which the fossil had been previously recorded, and with them were also found *Waldheimia cardium*. Mr. Wickes also identified the bed 2 as corresponding with the rich fossil-bed he has

* "Geol. parts of Wiltshire and Gloucestershire," *Mem. Geol. Survey*, 1858, p. 14.
† *Mem. Jurassic Rocks*, vol. iv. "Lower Oolitic Rocks of England," p. 268.

so successfully worked at Murhill and Ancliff.* A few Polyzoa were obtained, but the Coral-bed which elsewhere overlies the Polyzoa-bed was not detected.

Leaving the quarry the members walked down the pleasant combe to Long Dean, and then proceeded up the deep and charming valley leading to Castle Combe. Taking a peep at the comfortable-looking mansion long held by the Scrope family, and of special interest as the former home of G. Poulett Scrope, the eminent geologist, the members proceeded through the picturesque stone-built and stone-tiled village to the summit of the hill. Rejoining their conveyance they were driven by way of Grittleton and Hullavington to the King's Arms at Malmesbury. After paying a visit to the fine old Abbey the members took tea, and the Director distributed prints of a fossil obtained more than thirty years ago by Wm. Buy, from the Forest Marble of Malmesbury. This was the oldest known British Crab, *Palæinachus longipes*, described by Dr. Henry Woodward,† who had kindly sent the prints of the fossil.

The Crab was allied to the Spider Crabs (*Maia*), and to the Japanese Crab (*Inachus*), and Dr. Woodward had attributed the long duration of the form to its fecundity, for a modern female *Maia* would lay about 76,000 eggs.

III.—Derry Hill, Bowood, and Calne.

By H. B. Woodward.

On Whit Monday the members started along Wood Lane and across the meadows to the Forest Brickyard by the Wilts and Berks Canal. On the way they ascended the slope which forms the escarpment of the Kellaways Beds, and the Director remarked that the Kellaways Rock had been found in the form of doggers in the Chippenham Cemetery. The view northwards from near the reservoir of the Chippenham water-works overlooked the dip-slope of the Forest Marble and its overlying Cornbrash, while southwards the Corallian escarpment of Derry Hill was a well-marked feature.

A richly fossiliferous bed of Kellaways Rock was exposed at the base of the brick-pit, and this was broken up with the help of Mr. Simeon Gregory, of Derry Hill, who, for a while acted as pioneer.

Only one Brachiopod was found in this pit (*Rhynchonella*), but in addition to most of the Mollusca found at Kellaways the following were also met with: *Actæon*, *Alaria trifida*, *Natica punctura*, *Turbo elaboratus*, *Arca*, *Astarte*, *Cardium cognatum*, *C. Crawfordi*, *Isocardia minima*, *I. tenera*, *Lucina despecta* (?), and *Nucula*.

* See "Report of Excursion to Bradford-on-Avon," etc., *Proc. Geol. Assoc.*, vol. xiii, p. 135.
† *Quart Journ. Geol. Soc.*, vol. xxii, p. 493.

After crossing the Canal at two points the members took the footpath to the foot of Derry Hill where, at Mr. Gregory's cottage, a number of fossils from the Lower Calcareous Grit were seen and tranferred to the pockets and bags of the members. Among these were moulds of the middle part of a gigantic *Ammonites cordatus*, that presented a corkscrew-like aspect. Ascending Derry Hill, a locality mentioned by the Rev. Joseph Townsend as yielding good road-stone, the members inspected the quarry a little north of the high road on the way to Studley. Sands with hard bands of calcareous grit were here exposed, but the beds were singularly devoid of fossils. They represented the Lower Corallian or zone of *Ammonites perarmatus*.

Permission had been kindly granted by Mr. H. Herbert Smith, the agent to the Marquis of Lansdowne, for the party to pass through the park of Bowood by the Golden Gates. This, however, was not practicable, and the members entered by the humbler gateway near Christ Church.

After viewing the mansion the party proceeded by Buck Hill to the Black Dog siding, where the Rev. H. H. Winwood joined them. Thence crossing the River Marden and the Canal by New Mill, they ascended the hill by Conigre Farm to the quarries there opened in the Lower Calcareous Grit.

Here a fine example of *Ammonites perarmatus* at once attracted notice, and was secured for the Museum of Practical Geology. The Director said he had (perhaps injudiciously) remarked to the quarrymen that it was a very fine specimen, but so large that he could not run away with it. "We know'd that, sir," said one man, "or we should not have left it lying about." The fact is, fossils are a good deal sought after in the Calne district, and the quarrymen take good care of those they find. On the present occasion they produced from their shed a number of other specimens. Among these were the casts of *Am. perarmatus* to which the name of *A. catena* was originally given, because the internal casts of the chambers are often linked together like a chain; as well as several varieties of *Am. cordatus*, one an extremely inflated form, also *Belemnites abbreviatus*, *Natica*, *Gresslya peregrina*, *Gryphæa dilatata*, *Modiola*, *Ostrea flabelloides*, *O. gregaria*, and *Pecten vagans*.

Proceeding by Chilvester Hill and Curzon Street to the freestone quarry east of the Workhouse at Calne, a fine section of white false-bedded oolite with marly partings was seen—the whole somewhat dazzling in the sunshine. These beds, as was pointed out by the Director, are known as the Coralline Oolite, and together with the Coral Rag which locally overlies it, they represent the Upper Corallian or zone of *Ammonites plicatilis*. The locality was a noted one for *Hemicidaris intermedia*, nests of which are from time to time found. Mr. John Rhodes, when collecting fossils for the Geological Survey, had seen the bed laid

bare in 1887, and obtained many specimens, while the Director who had been there before had not obtained one. Mr. Rhodes was then informed by the quarrymen that they had not found any of the fossils for seven years. The layer containing the *Hemicidaris* occurred, at that date, about 16 feet beneath the surface towards the western side of the quarry. On the present occasion traces of Echinoderm spines were found, but no specimen of *Hemicidaris* was obtained from the rock. One example was picked up by Mr. Herries, and *Echinobrissus scutatus* was also found. The fossil-bed was not favourably exposed, but representatives of the following fossils were obtained: *Cerithium*, *Chemnitzia*, *Littorina muricata*, *Nerinæa*, *Pseudomelania* (?). *Gervillia acuta* (?), *Isocardia*, *Lima rigida* (?), *Modiola*, *Opis Phillipsi* (?), *Pecten fibrosus*, *Cidaris florigemma*, *Echinobrissus scutatus*, *Hemicidaris intermedia*, *Pygurus*, and *Serpula*.

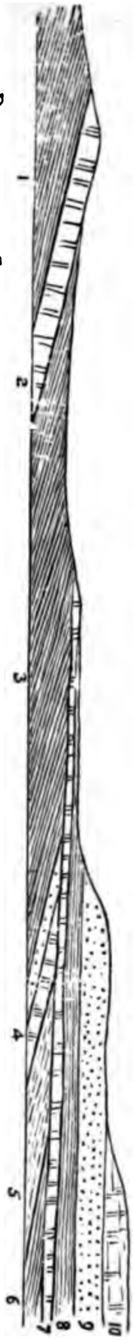
After examining the dressed blocks of Calne freestone, which is locally employed for building-purposes, the members proceeded along the Strand of Calne to the Lansdowne Arms, where a short halt was made.

Leaving Calne and proceeding along the Marlborough Road towards Quemerford, a fine view was obtained near the cemetery of the Cherhill White Horse, which was cut in the Chalk escarpment about 200 years ago. After leaving Quemerford village the footpath was taken towards Blackland, across rich meadow-land with fine oaks and elms, situated on the "Oak Tree Clay" (Kimeridge Clay) of William Smith. In this pastoral region nothing was seen of that formation nor of the succeeding Lower Greensand and Gault, whose outcrops were crossed in the vale between Quemerford and Calstone Wellington. A deep road cutting near the Calstone School showed the pale-brown micaceous sandstones of the Upper Greensand. Here *Ammonites rostratus* and a form like *A. auritus*, as well as *Arca carinata* were found.

Mr. Jukes-Browne, who had kindly furnished the Director with some notes on the Cretaceous rocks, had observed that north of Devizes the Upper Greensand became thinner; it was reduced from 160 or 170 feet to about 60 feet in the area now visited. The upper green glauconitic sands were no longer to be found, and we had only the lower beds of malmstone and sandstone. Moreover, there was not so conspicuous an escarpment as near Devizes (see Fig.), and the beds of Upper Greensand in places form one continuous slope with the Chalk Marl.

The Members walked a short distance on to the outcrop of the lowest Chalk, and after taking a brief peep at the fine Chalk escarpment of the Marlborough Downs, they retraced their steps to Calne by way of Theobalds Green, and then took train to Chippenham.

An agreeable surprise awaited them after dinner. It appears



DIAGRAMMATIC SECTION TO SHOW THE RELATIONS OF THE OOLITIC AND CRETACEOUS STRATA IN WILTSHIRE.

1. Oxford Clay.
2. Corallian Beds.
3. Kimeridge Clay.
4. Portland Beds.
5. Purbeck Beds.
6. Wealden Beds.
7. Lower Greensand.
8. Gault.
9. Upper Greensand.
10. Chalk.

H. B. Woodward, "Geology of England and Wales," Edn. 2, Fig. 58.

that Mr. J. T. Day, not feeling inclined for further walking, had remained in the Workhouse Quarry. He had interviewed an old quarryman, and with so much success that he had acquired about fifty examples of the *Hemicidaris.* These he generously presented to the Members, and considerable amusement was caused by the process of distributing them after drawing lots.

IV.—BOX AND CORSHAM.

BY THE REV. H. H. WINWOOD.

ON Tuesday, May 26th, the party travelled by train from Chippenham to Box, where they met Mr. Winwood, who acted as Director for the day, and were conducted by him to the "Clift," one of the entrances to the great underground quarries worked by the Bath Stone Firms, Limited. It is about a mile from Box Station, and on arrival, the party were received by Mr. George Hancock, the Managing Director of the Company. Pointing to a large-scale plan of the workings, he explained their extent. The following is the substance of his remarks:

The extreme points of the Bath freestone area now being quarried are—

At Box and Corsham on the North,
At Monks Park, Corsham, on the East,
At Combe Down, Bath, on the West, and
At Westwood, near Bradford-on-Avon, on the South.

Speaking generally, the dip of the workable strata is about 1 in 30, in a direction north-west to south-

east. Both gradient and direction are, however, subject to many local variations.

In most of the quarries the workable beds lie above the railway-levels. The quarries are connected with the railway by tramways, along the descending gradient of which the low stone-laden trolleys run by their own weight, the pace of each trolley being regulated by the brakesman who invariably rides upon it. Altogether there are between 30 and 40 miles of tram-line.

At a number of points the workable beds are reached by sinking inclined shafts from the surface, and the stone is drawn up the shafts by steam power. At other points, where the conformation of the surface admits of it, adits are driven into the workable beds from the sides of the hills.

The entrance to the Box Hill quarries, and through them one of the ways to the Corsham quarries, is through a doorway in the side of Box Hill. It is right in the workable beds of freestone, the quarry roof at that point being about 460 feet above Ordnance Datum.

The Box Ground beds are an earlier deposit than the Corsham beds; but owing to the dip of the strata, and to the Box Ground lying east of the Corsham beds, the Box Ground beds lie at a higher actual level than the Corsham. There is no known area in which both series possess any commercial value. On the contrary there is, between the Box and Corsham district, a tract of ground some few hundred yards in width, in which both stones are found, the Corsham beds overlapping the Box Ground. But in this area each stone is found to be inferior in quality and texture, in soundness and thickness of bed, to the stone-beds of the same series in adjacent areas, and to be unfit for building-purposes, and therefore this "bastard" area is left unworked.

In the Box Ground district the aggregate thickness of the freestone which is being quarried varies from 10 to 22 feet. The depth of the working is entirely governed by the quality of the stone, those beds which are not of good quality being left unquarried, although they may be of the same character geologically as the best beds.

In the Corsham district the total thickness of the beds quarried varies from 6 feet to 24 feet. In the shallower workings the Corngrit and beds below are not quarried, while in most of the deeper workings the whole series is quarried; that is, if each bed is of a good marketable quality.

Having entered the doorway in the side of the Box Hill and passed along a gallery about 8 feet high, the roof of which is mostly arched over, the ordinary roadways are soon reached. These are from 10 to 12 feet high, and 10 to 20 feet wide. The roof consists of the "rag" beds which overlie the freestone—coarse, shelly beds, which are of no value as building-materials. The floor is made up of the stone *débris* from the workings, a

tramway of 2 feet 6 inches gauge being laid along the centre. The sides are either the unquarried stone which is left as pillars, or walls or heaps of quarry *débris*.

Ventilation is secured by sinking shafts. If in any direction the air gets close and foul by reason of the workings being at a great distance from the main drift-ways, the matter is at once remedied by sinking an air-shaft from the surface. The stone is mostly from 60 to 120 feet below the surface, and the sinking of a shaft is not a very serious matter. Good air can always be depended upon, and there is plenty of headway and elbow-room.

Winter and summer the temperature is about the same, say, from 52 to 56 degrees.

Faults of any consequence are met with but seldom. In the Box and Corsham district only three deep faults, or "jumps," have had to be crossed. The practice is to cross these "jumps" at as few points as possible, and from each crossing to lay out the quarry workings right and left in lines parallel with the direction of the "jump." Roughly speaking, about three-fourths of the stone is quarried out, the remaining fourth part being left in as pillars to support the overhead strata.

Here and there the roof is propped with timber, whole larch being preferred for this purpose.

The ceiling bed in some parts of the Corsham district is so sound and strong that the galleries are excavated 40 feet or more in width.

Immense lengths of working-face are presented by the numerous galleries. From the western entrance to the Box Hill quarries to the eastern entrance to the Corsham quarries the distance is about two miles in a bee-line. Half a mile of this consists of a tunnel cut through the "bastard" stone for the purpose of connecting the Box Hill and Corsham quarry workings.

The party then followed Mr. Hancock into an underground gallery, and a neat little tin benzoline lamp, mounted on a wooden handle, was provided for each of the Members.

After traversing many complicated galleries and workings, the party arrived at a shaft which admitted daylight, and were informed that they were in the "Cathedral working." Mr. Hancock continued his explanation as follows:

A feature of interest in the Box Hill quarries is the "Cathedral" working. The name is not an inapt one, for the workings take somewhat the form of a lofty-arched nave and choir, transepts and chapels. Portions of the workings are lighted from two shafts, one of them of large dimensions, up which the stone was formerly drawn to the surface; the other a smaller shaft, which afforded ingress and egress to the quarrymen. From the floor of the working a well is sunk down to the fuller's earth. Thus the entire section of the Oolite, from the surface of the ground to the

fuller's earth, is exposed at this one point. It is made up as under:

(*a*) 38 feet in thickness of alluvial soil and thin shelly beds.
(*b*) 24 feet of Box "Scallett" beds—a fine, close freestone. These beds were quarried over the whole area of the Cathedral working before it was found that it would not stand the weather, and then the
(*c*) 10 feet of "rag" beds were sunk through to the
(*d*) 17 feet of "Box Corngrit," which was also quarried over the whole area of the working, and until its non-weather properties were proved, when
(*e*) 5 feet more of "rag" beds were sunk through, and immediately below these was found
(*f*) 18 feet of the best Box Ground "weather-stone." Below the Box Ground stone is
(*g*) 17 feet of "rag" beds, the lowest of which rests upon the fuller's earth, making a total depth of

129 feet.

It is in the (*f*) Box Ground stone-beds that all the Box Hill workings are carried on. Neither the Box Scallett nor the Box Corngrit is now quarried, both stones being inferior in quality, soundness and weather-properties to the Corsham stone.

The Corngrit which is known to architects and builders to-day is found in the Corsham series of beds, and is entirely different from the Box Corngrit. It makes its first appearance in the south-east part of the Corsham district, immediately below the Corsham beds. It is then from three to five feet thick. In some spots it is in one bed, but more often it "heaves" in two. As the workings proceed to the north and north-west, the Corngrit is found higher and higher up amongst the Corsham beds, until, at the northern limits of the workings, it is above them all, resting upon the topmost one. Where the Corsham beds are above the Corngrit, they are fairly level, subject only to the general dip. But where they lie underneath the Corngrit, they are subject to false-bedding, in most places very pronounced. The Corngrit differs from the Corsham stone chiefly by reason of possessing numerous small bodies of calcite, which take many forms. The quarrymen call these small bodies of calcite "oats," "reap-hooks," "pins," etc. The mass of the stone is generally firmer and closer in texture than the Corsham.

The bulk of the Bath stone which is sold during the winter has had a summer's seasoning in the open air, and the stone quarried in the winter is stacked away underground in the old workings until the spring. To this rule there is, however, one notable exception, and only one, viz., the Box Ground stone. This stone, owing to its exceptional weather-resisting qualities, is

sent to buildings in a perfectly green state throughout the winter season. One day it is a part of the bed-rock of the hill, the next day it is hewn out in blocks, and, with all its quarry sap in it, is brought out from the mine into the hardest frosts without injury.

Method of Quarrying.

The quarrymen work in gangs of from four to a dozen or so, each gang having allotted to it a width of about 80 ft. of rock. Nearly up to the face of the rock and about halfway across the width a tramway is laid, and at the end of the tramway a ten-ton crane is erected, the upper part of the crane pillar being fixed in the quarry roof, and the lower part in a large block of stone in the floor. In the way which will presently be described, a heading about 20 feet wide (called the "straight") is driven forward in about the centre of the 80 feet, and "side holes" are driven right and left to the limits of the 80 feet strip. Between the side-holes sufficient rock is left unquarried to serve as pillars to support the roof.

The initial operation consists in picking out, by means of a double-headed pick, a narrow horizontal gap in the freestone close up to the ceiling. This gap, which is called a "jad," is carried back into the rock at least 5 feet from the face. The pick-heads are fixed slightly obliquely on the handle, so that one point is at an acute and the other at an obtuse angle to the handle. By means of the obtuse angle point the picker can reach the far corners of the "jad," and make a clean, squared recess to receive the saws. The picking is done in the freestone rather than in the "rag," because it is much softer. A graduated series of picks are used, the "jad" being commenced with a heavy pick ($7\frac{1}{2}$ lbs. weight), and finished at the far end with a light one, about $4\frac{1}{2}$ lbs. weight, fixed on a 6 feet handle.

When the "jad" is finished, the next operation is to insert, about midway across the "jad," a one-handled saw into the space, and to cut down at right angles to the face about 3 feet 6 inches to 4 feet 6 inches, according to the thickness of the bed or beds, the aim being not to cut deeper than to give sufficient space for a man to enter when the beds are removed. A second saw-cut is next made some 3 or 4 feet to right or left, and at a slight angle to the first cut, so that the piece of stone which lies between the two cuts is narrower at the back-end than at the front, to facilitate its being drawn out of its position in the rock. This piece of stone is now joined to the rock at the back-end only. Wedges are then driven under the front of the piece until it is forced up from its bed and broken off at the back. This stone is called the "wrist" stone (? wrest). It is drawn forward with bars or chain, and its removal leaves a chamber five feet long, and between three and four feet wide, and four feet or so in height. Into this chamber the

quarryman gets, passing a long one-handled saw (6 or 7 feet long) over the top of the rock, and, sitting on a low stool at the far end of the chamber, proceeds to make a saw-cut along the back of the "jad," parallel to the face, and down to the floor of the small chamber. Having done this on one side, he turns himself round, and, facing sideways in the opposite direction, he repeats the operation on that side also. Other saw-cuts are made from front to back, and in this way the beds of rock are broken into and cut up into blocks of such sizes as it will yield. Water is conveyed into the saw-cuts from vessels placed on the rock, by which means the stone-dust becomes soft slush, and is drawn out from the cut as the saw is drawn backwards. When the blocks are cut off from the rock they are attached to the crane by a chain, and drawn from their position on to level ground, where they are carefully examined as to their soundness, and are trimmed and shaped fit for sale. This is done with axes (double-headed hatchets, about 14 lbs. each), and the operation is called scapling (? scalping, taking off the skin). When made ready for sale, the blocks are lifted with the crane and placed on low trolleys, which are conveyed to the railway loading-wharf or to the stacking ground, as the case may be. The beds below the picking standing are readily sawn up into blocks, and treated in the same way.

Blocks that are less than nine inches in thickness are too thin to be of value. One hundred cubic feet (more than six tons) is the limit of single blocks unless required for special purposes, when blocks up to nine or ten tons can readily be obtained.

Mr. Winwood observed that the word "Scallett" was of very doubtful origin: might it be connected in any way with the word "scalings"—those beds which were scaled off the top, and of less value? The "weather stone" spoke for itself as being that which, when exposed, stood the action of the weather better than any of the other beds. Mr. Hancock pointed out on the faces of the "ground stone" the marks (called "jaddings") of the picks by which the stone was originally worked, and the triangular impressions of the wedges used for detaching the blocks. The lofty pillars of "Freestone," left to support the floors and the cross workings, gave the not inappropriate name of Cathedral to this old working.

Previously to this, Mr. Hancock turned off the main road to the end of one of the sidings, where a gang of men were at work, and gave a most interesting and minute account of the way in which the large blocks of Freestone were sawn out. The whole process of picking, sawing, and wedging was gone through, and the members saw the crane detach a large block of more than five tons, torn from its base and dragged up the slope of *débris*.

Resuming the traverse to the Corsham end, the faults—one a throw of some 10 ft.—were pointed out, and attention was drawn

to the way in which the roof was supported by larch poles, periodically examined by competent men from time to time to secure the safety of the workmen. Numerous cracks and fissures overhead were sufficient evidence of the care required in this respect. A long flight of stone steps lead to the bright sunlight, somewhat trying to the eyes of those who had been two hours and a-half in the darkness underground.

Before mounting the conveyances the President, Mr. Newton, cordially thanked Mr. Hancock, in the name of the Association, for the treat he had given the members, and the kind and able way in which he had answered all their troublesome questions.

Mr. Hancock, in reply, said it had been a pleasure to him to conduct the party through a small portion of the workings in the Bath mines. He only regretted that there was not time to inspect many more of the workings. The district had been by no means exhausted, and he would be happy at any time to receive a visit from any member of the party or their friends, and to take them through the same, or any other portion, of the district, doing his best to make their visit both useful and interesting.

A short drive through Corsham Side and Worm Wood was then taken to Mr. Shepherd's quarry on the left of the Devizes road, about one mile from Atworth. After a few preliminary remarks from the Director, who stated that they were now on the roof, as it were, of the "cathedral," and were then looking at the beds which succeeded those they had seen at the mouth of the old shaft, the white oolitic beds at the base of the section representing probably the last bed of the great oolite, and the fissile beds above, without any intervening "Bradford Clay," representing the commencement of the Forest Marble series, hammers were busily plied, and many characteristic fossils obtained, of which the following were afterwards identified: *Saurian* teeth, *Hybodus grossiconus*, *Strophodus tenuis*, *Lepidotus*, *Mesodon*, *Cerithium muricatum*, var. *Astarte ungulata* (?), *Gervillia crassicosta*, *G. ovata*, *Lima cardiiformis*, *Lima* sp., *Modiola*, *Ostrea gregaria*, *O. subrugulosa*, *Pecten vagans*, *Plicatula fistulosa*, *Rhynchonella*, Polyzoon, Echinoderm plate and spine, Crinoid ossicle. Some fine ripple-marked slabs of Forest Marble were noticed. The thinner beds of this formation are still (as of old) shaped into stone tiles for roofing purposes.

Two other sections were then examined; one on the right exposed a thick bed of blue clay, streaked with yellow veins, and laminæ of fissile limestone resting on thicker beds of the series; that on the left, Mr. York's quarry, exhibiting the same series of the lower beds of the Forest Marble as the first. The quarrymen here seemed quite indifferent as to the existence or otherwise of fossils, stating that it spoiled good stone to knock them out, and, moreover, that it was not worth their while to preserve them; notwithstanding this discouraging statement, several members were

successful in finding both Saurian and Fish teeth. Remounting the brakes, and returning to Corsham, a meat tea at the "Methuen Arms" was partaken of, in time for the 5.3 p.m. train for London.

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1877. BLAKE, J. F., and HUDLESTON, W. H.—"On the Corallian Rocks of England." *Quart. Journ. Geol. Soc.*, vol. xxxiii.

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ORDINARY MEETING.

FRIDAY, MAY 1ST, 1896.

DR. G. J. HINDE, F.R.S., Vice-President, in the Chair.

The following were elected Members of the Association:—Col. Bushe; J. J. Hamling; M. H. Heys.

The following papers were read:

"On the Physical Geology of the Island of Purbeck," by AUBREY STRAHAN, F.G.S.

"On the Brachiopoda of the Skiddaw Slates," by J. POSTLETHWAITE, F.G.S.

ORDINARY MEETING.

FRIDAY, JUNE 5TH, 1896.

E. T. NEWTON, F.R.S., President, in the Chair.

The following were elected Members of the Association:—William McNeill; Capt. Anderson; A. K. Coomora Swamy; C. R. Sillem.

A lecture was delivered by Prof. JOHN MILNE, F.R.S., on "Bradyseisms, Earthquakes, and other Movements of the Earth's Crust," and was illustrated by the lantern, horizontal pendulum, seismometers, and other apparatus especially lent by Mr. LOUIS CASELLA.

Mr. LEIGHTON exhibited a specimen of Bargate Stone from Dorking.

Mr. NEWTON showed *Ammonites cordatus* from Calne.

Mr. HERRIES some large specimens of *Hemicidaris intermedia* and other fossils from Calne and Yorkshire; and

Mr. DIBLEY, *Ptychodus lævis* teeth from the Chalk of Burham, and a mass of Flint full of *Echinoconus* from Gravesend.

ORDINARY MEETING.

FRIDAY, JULY 3RD, 1896.

E. T. NEWTON, F.R.S., President, in the Chair.

The following were elected Members of the Association:— F. C. Crawford; B. A. Baker.

Mr. F. W. RUDLER exhibited, on behalf of M. N. DE MERCEY, a specimen of "rich phosphate," containing 65 per cent. of phosphate of lime, recently found by M. DE MERCEY in a pipe in the Phosphatic Chalk of Taplow.

The following papers were read with reference to the Long Excursion:

"On the Palæozoic Rocks in the districts of West Somerset and North Devon to be visited during the Long Excursion," by HENRY HICKS, M.D., F.R.S., with

"Notes on the Fossils of the Pickwell Down, Baggy, and Pilton Beds," by the Rev. G. F. WHIDBORNE, M.A., F.G.S.; and

"Notes on the Trias, Rhætic, and Lias of West Somerset," by the Rev. H. H. WINWOOD, M.A., F.G.S.

:E PALÆOZOIC ROCKS OF WEST ;OMERSET AND NORTH DEVON,

SPECIAL REFERENCE TO THE DISTRICTS TO VISITED DURING THE LONG EXCURSION OF

By HENRY HICKS, M.D., F.R.S., P.G.S.

[*Read 3rd July, 1896.*]

I.—INTRODUCTION.

[OUGH the rocks in the districts to be visited by the :ologists' Association during the Long Excursion belong ıratively few formations, they have led to many and pro-

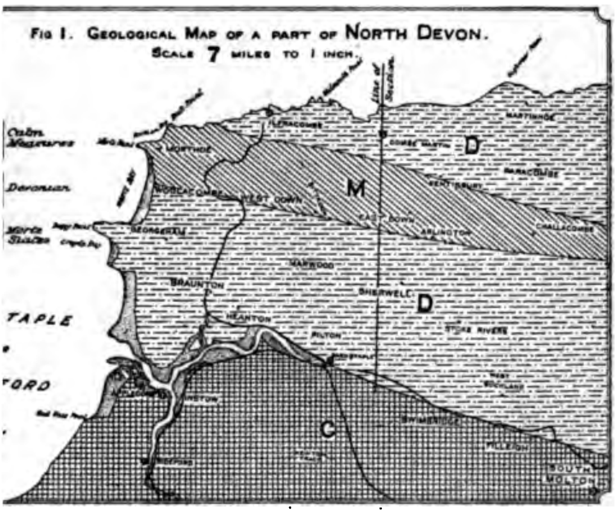

FIG. 1.

:ontroversies in the past, and are still a fruitful source of ›n.

history of these controversies has been so often written ill be unnecessary to refer to them beyond pointing out ı differences in the views held in regard to the interpreta-he succession and the classification of the rocks.

Palæozoic rocks of West Somerset and North Devon were l by De la Beche and described by him in his *Report on 'ogy of Cornwall, Devon, and West Somerset*, published in He there classes all the rocks north of a line taken from ›le through Swimbridge and Brushford to Clayhanger as acke," and those immediately south of that line as the

"Carbonaceous Series." For the beds classed as "Grauwacke" by De la Beche, the term "Devonian" was used by Sedgwick and Murchison in the year 1839, and the majority of those who since then have examined and described these rocks have adopted that name for them.

In the year 1866 Professor Jukes endeavoured to show that the rocks classed as Devonian by Sedgwick and Murchison did not constitute a separate system from the Carbonaceous Series, and that they should, in reality, be classed with the Carboniferous rocks. He also maintained that the interpretation of the succession as previously given was incorrect, that the beds had been repeated by faults, and that the thickness of the series had been greatly exaggerated. His views received at the time but slight support, and were afterwards strongly controverted in papers by Mr. Etheridge, Mr. Townshend Hall, Mr. Ussher, and others.

In the year 1890, after an examination of many of the sections in the neighbourhoods of Morthoe, Ilfracombe, and Combe Martin, I expressed the opinion that I believed Professor Jukes was correct in stating that the beds had been repeated by faults, and were of much less thickness than was usually supposed, but that he was incorrect in placing the Morte Slates at the top of the series, as I had found evidence to show that they were the oldest rocks in the area (mainly of Silurian age) and could not possibly occur at the points in the succession where placed by him or by Sedgwick and Murchison. Though the thickness must be greatly reduced, it seems but fair that the name Devonian should still be used for those rocks which lie between the Silurian and the typical Carboniferous, even if they be equivalent, in part, to beds ranked as Lower Carboniferous elsewhere, as they mark a definite geological and palæontological horizon.

For our knowledge of the rocks and their fossil contents we are indebted to the labours of Sedgwick and Murchison, D. Williams, Weaver, Lonsdale, De la Beche, Phillips, Salter, Pengelly, Jukes, Townshend Hall, Mules, Valpy, Perceval, Etheridge, Champernowne, Ussher, Winwood, Whidborne, Hamling, and others.

II.—Physical Features.

The Palæozoic rocks occupy the mountainous and most picturesque areas in West Somerset and North Devon, and are traversed by many valleys and ravines of great beauty. The Quantock Hills, being in the most easterly district to be visited, will first come under observation. They run in a direction from N.W. to S.E., and consist mainly of Devonian rocks, but with Mesozoic strata surrounding them. The Quantocks are separated from the main mountainous districts of West Somerset by the wide valley through which the railway from Taunton to

Watchet runs. From the west side of this valley the Palæozoic rocks extend continuously westward for over 40 miles, reaching the coast line at Ilfracombe, Morte Bay, and Barnstaple Bay. The main mountainous areas are the Brendon and Croydon Hills and Exmoor Forest, but there are many other uplands (Downs) which attain to a considerable height. As many of the valleys are deep, and often cross the strike of the beds, good exposures of the rocks sometimes occur along their sides; but it is along the coast-line, which also is bold, rugged, and indented by numerous creeks, that the best sections are exposed.

III.—Morte Beds.

These rocks have recently been fully described in a paper by me in *The Quarterly Journal of the Geological Society*, vol. lii (May, 1896), p. 254. I there maintain that they are the oldest rocks in the area, and that the fossils show them to be mainly of Silurian and Lower Devonian age. A great thrust fault extends continuously along the northern boundary of the Morte Slates, from the coast near Ilfracombe to the Exe Valley. On the south side there is evidence generally also of a well-marked fault; therefore beds belonging to different horizons in the succession come in contact with the Morte Slates. Beyond the Exe Valley the boundaries are again faulted ones; but the results are not so marked as in the areas west of the Exe Valley. The Morte Slates are mainly fine-grained grey slates, much folded, and dipping at a high angle. The strike is usually from about W.S.W. to E.N.E. The following is a list of the chief fossils hitherto discovered in these beds by the Rev. G. F. Whidborne, Mr. J. G. Hamling, and myself at Barricane, in Morte Bay, and Mullacott and Shelfin near Ilfracombe:

Lingula Mortensis, Hicks.
Stricklandinia lirata, Sowerby.
Rhynchonella Lewisii (?), Davidson.
Rhynchonella Stricklandi (?), Sowerby.
Spirifera Hamlingii, Hicks.
Orthis rustica, Sowerby.
Modiolopsis barricanensis. Hicks.
Pterinæa Mortensis, Hicks.
Also Encrinites and Graptolites.

The fossils found in the beds usually classed with the Morte Slates in West Somerset are now being described, and belong to the following genera—*Orthotetes*, *Strophodonta*, *Leptæna*, *Rhynchonella*, *Avicula*, *Phacops*, *Cryphæus*, Encrinites, etc. These fossils show that the beds belong to higher horizons than those which have yielded fossils in the Morte Series in North Devon, and that they are, for the most part, of Lower Devonian age. Up to the year 1890 it was supposed that the Morte Slates were entirely unfossiliferous, but in that year I found fossils in them,

and since then they have yielded, as mentioned above, a fairly rich fauna.

IV.—Foreland and Lynton Beds.

These and the following beds are described according to their geographical position from north to south; and the arrangement is not intended to explain the relative stratigraphical position of the beds beyond each limited area.

The Foreland, a prominent point on the shore of the Bristol Channel, rises to a height of 659 feet. The beds are mainly hard purple, red, and grey sandstones, with occasional bands of conglomerates. They are bent into wide folds with dips to the north and south, and extend along the coast eastward to Minehead. Plant remains, and Annelid burrows only have as yet been found in these beds. They are stated to support the Lynton beds which consist of * "hard grits, shales, and sandstones, intersected with occasional bands of calcareous and ferruginous matter. The fossils are few in number, and imperfectly preserved, being either crushed and distorted or occurring as impressions or casts only. In the Valley of the Rocks, at Watersmeet, Woodabay, and Barbrick Mill, all in the neighbourhood of Lynton, the most characteristic fossils are: *Favosites cervicornis*, *Fenestella antiqua*, *Chonetes Hardrensis*, *Orthis arcuata*, *Spirifera hysterica*, *Spirifera lævicosta*."

Mr. Etheridge, in the *Quarterly Journal of the Geological Society*, vol. xxiii (1867), gives the following as occurring also in the Lynton beds: *Steganodictyum* sp., *Alveolites suborbicularis*, *Fenestella arthritica*, *Petraia pluriradialis*, *Actinocrinus tenuistriatus*, *Orthis granulosa*, *Spirifera canalifera*, *Streptorhynchus umbraculum*, *Pterinæa spinosa*, *Ctenodonta Krachtæ*, *Megalodon cucullatus*, *Pleurotomaria aspera*, *Bellerophon striatus*.

Mr. Valpy mentions (*Notes on the Geology of Ilfracombe*, Twiss and Sons) that he had found *Tentaculites scalaris* at Woodabay, and near Watersmeet a very large *Rhynchonella*. He also mentions a bed very rich in fish remains near the ladies' bathing place which deserves examination.

Fossils are fairly abundant in some calcareous beds on the shore between Lynmouth and the Foreland, but owing to their highly indurated condition it is most difficult to obtain any good specimens. This band is evidently low in position in the series, and in some of the associated beds pebbles of considerable size are fairly abundant. In a road-cutting near the Valley of Rocks Hotel, two years ago, I found many of the above-mentioned fossils in a fairly good state of preservation, and any new exposures in that immediate area would well deserve careful

* Townshend Hall, "*A Sketch of the Geology of Devonshire.*" Published by W. White Sheffield, 1878.

examination. The Foreland beds, as well as the lowest beds of the Lynton series, must have been deposited in comparatively shallow water not far from shore.

V.—HANGMAN, COMBE MARTIN, AND ILFRACOMBE BEDS.

The *Hangman Beds* are well exposed in precipitous cliffs between Woodabay and Combe Martin Bay, and derive their name from the Little Hangman Hill. They are mainly hard red, purple, and grey grits, sandstones, and shales. They extend continuously from the Little Hangman Hill into North-West Somerset, and occur at a height of over 1,700 ft. at Dunkery Beacon on Exmoor. At Timberscombe, south of Minehead, we last year found a band of shale, interstratified with the sandstone, covered with Plant remains; and the Rev. H. H. Winwood has made known the discovery of fossils in beds of this age at Alfoxton and Holford, in the Quantock Hills.* Iron ore occurs frequently in the beds at the base of the series.

Combe Martin Beds.—These beds have usually been classed with the Hangman Beds, but, as they form passage beds between the latter and the Ilfracombe Beds, and mark a very definite fossil horizon, I have thought it well to call them by the name of the place from whence most of the fossils have been obtained.

The following genera are mentioned by Mr. Valpy as occurring in these beds, chiefly in the rocks on the east side of Combe Martin Bay, and in some small quarries under the Little Hangman:

"*Bellerophon*, *Cucullæa*, *Euomphalus*, *Macrocheilus*, *Myalina*, *Mytilus*, *Natica*, *Pleurotomaria*, *Sanguinolaria*, *Solen*, and two corals with *Fenestella*."

The beds in which these fossils occur are either highly indurated calcareous bands or quartzose sandstones and flaggy beds, and it is most difficult to obtain satisfactory specimens. Still, they would, I feel sure, well repay a persevering search, as the fossils are there in abundance. The beds as shown in the section, Fig. 2, are much folded, and the fossil bands repeated many times.†

"The succession, as seen in the cliffs between Hangman Point and Combe Martin Harbour, indicates such an order of deposition as would accompany a gradual depression with a shore-line not far north of the Hangman Point. The lowest or massive grit and sandstone beds are clearly followed in true succession by the finer flaggy beds, and the latter by slaty and calcareous beds. Certain fossil zones which can be traced often offer evidence to prove that the beds are inverted when the folds are too much broken to be easily followed."‡

* *Proc. Bath Nat. Hist. and Antiq. Field Club*, vol. ii, p. 427.
† See H. Hicks. *Geol. Mag.*, dec. 3, vol. x, p. 3 (Jan. 1893).
‡ Hicks, *Ibid.*, p. 4.

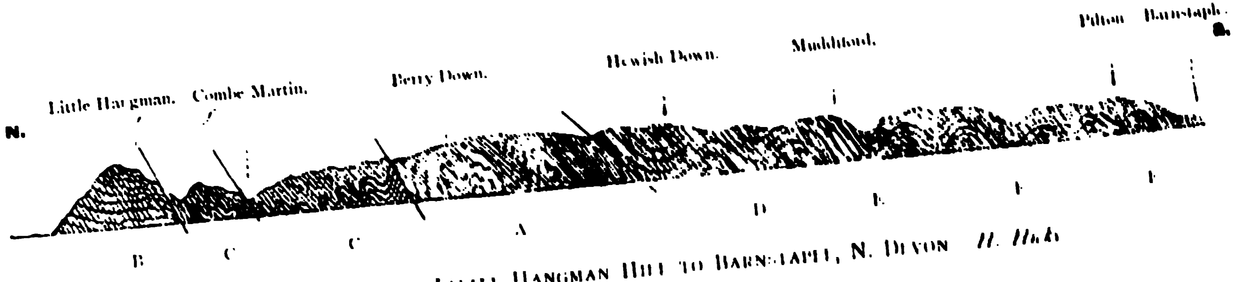

FIG. 2.—SECTION FROM LITTLE HANGMAN HILL TO BARNSTAPLE, N. DEVON

Length about 9½ miles

F Pilton Beds (shales and calcareous beds).
E Baggy Point beds (flags, etc.).
D Pickwell Down grits and sandstones

/// Faults

C Combe Martin and Ilfracombe beds.
B Hangman Grits, etc.
A Morte Slates

FIG. 3.—SECTION ACROSS THE TORRS, SHOWING THE FOLDINGS OF THE BEDS.—*H. Hicks*

FIG. 4.—VIEW OF THE TORRS, ILFRACOMBE (ILFRACOMBE BEDS).
(From a photograph by A. R. Hunt Esq., M.A., F.G.S.)

Ilfracombe Beds.—These are mainly flaggy, slaty, and calcareous rocks, and they rest conformably on the Combe Martin beds. In a westerly direction they extend to the coast at and south of Ilfracombe, and easterly as far as Nettlecombe in West Somerset. The beds are greatly folded, cleaved, and much broken. The "torrs" (Figs. 3 and 4), so characteristic of the areas where the Ilfracombe Beds occur, are due to the combined results of folds and fractures parallel with the lines of bedding. I have given many examples of the folds and faults in my paper in the *Geological Magazine*, just quoted; and papers by Dr. Sowerby * and by Mr. J. E. Marr † give numerous examples of the effects of cleavage on these rocks. The recent recognition of the unusually folded and fractured condition of these beds has shown that the thicknesses usually assigned to them have been much too great. Moreover the highest beds are generally in the centre of a main trough, and not, as was formerly supposed, where they come in contact with Morte Slates.

The following are the fossils mentioned by Mr. Etheridge and Mr. Valpy as having been found in these rocks, the chief fossil localities being the cliffs at the bathing places, Ilfracombe, Hagginton Hill, and Rillage, on the east side of Hele Bay, and the limestone quarries at Combe Martin, also in West Somerset at Luckwell, Wheddon Cross, Withycombe, Lod Huish, Goldsoncot, and Nettlecombe:

Steganodictyum cornubicum, McCoy.
Stromatopora concentrica, Goldf.
Amplexus tortuosus, Phill.
Cyathophyllum æquiseptum, Edw.
C. Boloniense, Blainv.
C. cæspitosum, Goldf.
C. helianthoides, Goldf.
C. obtortum, Edw.
Cystiphyllum vesciculosum, Goldf.
Favosites cervicornis, Blainv.
F. dubia, Blainv.
F. fibrosa (?), Goldf.
Hallia Pengellyi, Edw.
Heliolites porosa, Goldf.
Heliophyllum Hallii, Edw.
Michelinia antiqua, McCoy.
Pachyphyllum Devoniense, Edw.
Petraia pluriradialis, Phill.
Cyathocrinus macrodactylus, Phill.
C. variabilis, Phill.
Tentaculites annulatus, Schloth.
T. scalaris, Schloth.
Phacops (Trimerocephalus) lævis, Münst.
Ceriopora similis, Phill.
Fenestella antiqua, Goldf.
F. arthritica, Phill.
Glauconome sp.
Hemitrypa oculata, Phill.
Retepora repisteria, Goldf.
Athyris concentrica, V. Buch.
A. lachryma, Sow. (?).
Atrypa desquamata, Sow.
A. reticularis, Linn.
A. reticularis var. aspera, Schloth.
Cyrtina heteroclyta, Defr.
Merista plebeia, Sow.

* *Edinburgh New Phil. Journal*, vol. lv (1853), p. 137.
† *Geol. Mag.*, dec. 3, vol. v (1888), p. 218.

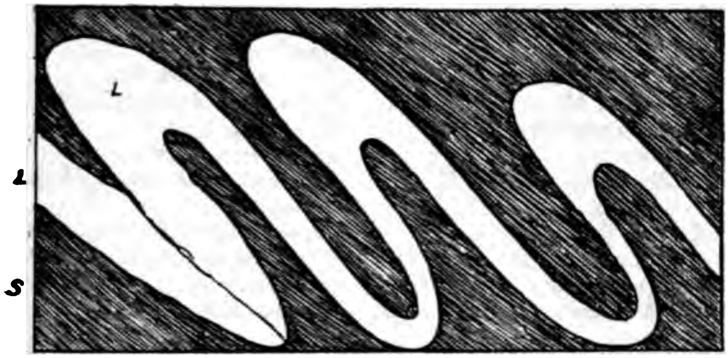

FIG. 5.—FOLDS IN BEDS: EAST SIDE OF HELE BAY.—*H. Hicks.*

L Limestone. S Slates.

FIG. 6.—BROKEN FOLDS DUE TO CLEAVAGE: EAST SIDE OF HELE BAY.—*H. Hicks.*

L Limestone. S Slates.
F F Faults.

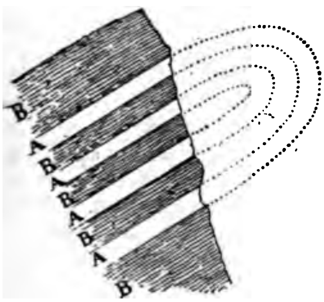

FIG. 7.—DECEPTIVE APPEARANCE OF SUCCESSION DUE TO FOLDING: HAGGINTON HILL.—*H. Hicks.*

A Limestone bands.
B Slaty beds.

Orthis interlineata, Sow.
O. striatula, Schloth.
Rensseleria stringiceps, Roem.
Rhynchonella cuboides, Sby.
R. pleurodon, Phill.
R. pugnus, Mart.
Spirifera canalifera, Valen.
S. curvata, Schloth.
S. disjuncta, Sby. (*S. Verneullii*, Murch.)
S. nuda, Sow.
S. speciosa, Schloth.
Stringocephalus Burtini, Def.
Streptorhyncus crenistria, Phill.
S. umbraculum, Schloth.
Strophomena rhomboidalis, Wahl.
Schizodus deltoideus, Phill.
Myalina, sp.
Acroculia vetusta, Sow.
Euomphalus radiatus, Phill.
E. serpens, Phill.
Macrocheilus brevis, Sow.
Bellerophon bisculcatus, Roem.
Conularia.
Orthoceras cylindraceum, Sow.
O. cylindricum, Sow.
O. Ludense (?).
O. tentaculare, Phill.

VI.—Pickwell Down, Baggy (or Marwood) and Pilton Beds.

The rocks which have been classed under the name Pickwell Down occur either on the south side of the Morte Slates, or repose upon them. They consist of red, purple, brown, and green grits and sandstones, with some intercalated bands of shale. Detrital Mica is very abundant in some of the beds, and they contain frequently, also, much broken felspar. They derive their name from Pickwell Down, on the east side of Morte Bay, and extend continuously from there to near Wiveliscombe, in West Somerset. The lowest beds are often deeply stained of a red colour, and iron ore is frequently found at this horizon. Hitherto it has been stated that no fossils occur in these beds; but during an examination of some of the lower beds in the Exe Valley, near Dulverton, in 1894, Mr. Whidborne and I found in them traces of fish remains and a band rich in fossil wood. It is doubtful whether any of the lowest beds are exposed in any of the areas, for generally a well-marked fault separates them from the underlying Morte Beds.

The *Baggy* (also called Marwood and Sloly beds) consist of sandstones, flags, and shales, usually of a grey, green, or yellowish colour. They are well exposed at Baggy Point, on the north side of Croyde Bay, and extend inland by Marwood and Sloly into West Somerset. These, and the overlying beds, have been carefully worked by Mr. Townshend Hall, of Barnstaple, and a magnificent collection of fossils made by him may be examined in the museum at Barnstaple. He frequently refers to these beds as the *Cucullæa* beds, from the abundance of these fossils at certain horizons in them. Fossils are very plentiful in the Sloly quarry, a few miles north of Pilton on the Barnstaple and Ilfracombe road, and fossil wood also occurs there in considerable abundance. Baggy Point and Marwood are also good localities for collecting.

The *Pilton Beds* take their name from Pilton, near Barnstaple, and are mainly grey flags and shales, with intercalated calcareous bands. They are richly fossiliferous, and exposures occur frequently all along a line extending from Croyde Bay by Braunton, Pilton, Goodleigh, East Anstey, and Brushford to near Wiveliscombe. In addition to the collection by Mr. Townshend Hall already referred to, important collections have also of recent years been made by Messrs. Porter, Whidborne, Hamling, and others, and Mr. Whidborne has very kindly furnished me with a very complete list of the fossils which are known to occur in the Baggy (Marwood and Sloly) and Pilton Beds, which will be found at the end of this paper. Mr. Whidborne will be very grateful to be allowed to examine any characteristic specimens that may throw fresh light on the fauna of these beds.

VII.—Carboniferous Beds.

In a recent paper* Dr. G. J. Hinde, F.G.S., and Mr. Howard Fox, F.G.S., have given an interesting account of discoveries of radiolaria and other fossils, made by them, Mr. Hamling, F.G.S., Mr. G. F. Tregelles, and others, in these rocks in North Devon and West Somerset. After referring to the usual description of these rocks "as consisting of a lower or basal series of dark argillaceous shales, with impersistent intercalated beds of dark limestone, which conformably succeed the fossiliferous shales and slates of the Upper Devonian," they say: "We have ascertained, however, that the division next above the basal limestones and shales, known as the Codden Hill Beds, is essentially of organic origin, and that it is filled to a great extent with the remains of radiolaria, thus probably forming one of the thickest deposits of these microscopic organisms hitherto known in the geological series."

The Carboniferous rocks are exposed at Barnstaple, and on the south side of Barnstaple Bay, and extend in a southerly direction as far as Boscastle and Tavistock, and in an easterly direction to Ashbrittle in West Somerset. The radiolarian beds are well exposed in quarries at Tawstock, Codden Hill, Hannaford, and Swimbridge in North Devon, and near Brushford and Ashbrittle in West Somerset.

The following fossils are stated by Dr. Hinde and Mr. Fox to occur in the Dark Limestones and Shales of Venn, Swimbridge, Bampton, and Fremington, N. Devon: *Posidonomya Becheri*, Bronn; *P. tuberculata*, Sow.; *P. lateralis*, Sow.; *Goniatites sphæricus*, Mart.; *G. crenistria*, Phill.; *G. striatus*, Sow.;

* "On a well-marked horizon of Radiolarian Rocks in the Lower Culm Measures of Devon, Cornwall, and West Somerset," *Quart. Journ. Geol. Soc.*, vol. li, p. 609.

Orthoceras cylindraceum, Sow., and in the Codden Hill beds, besides some 23 genera of radiolaria, the following other fossils:

Spicules of Hexactinellid Sponges
Pleurodictyum Dechenianum, Kayser.
Cladochonus Michelini, M. E. and H.
Petraia, sp. cf. *P. pauciradialis*, Phill.
Crinoidal stems.
Cyathocrinus distans, Phill.
Phillipsia Leei, H. Woodw.
Phillipsia minor, H. Woodw.
Phillipsia Cliffordi, H. Woodw.
Phillipsia sp.
Griffithides acanthiceps, H. Woodw.
Griffithides longispinus, Portl.
Proetus 2 sp.
Discina nitida, (Phill.).
Productus plicatus, Sarres.
Productus concentricus, Sarres.
Productus lævipunctatus, Sarres.
Chonetes rectispina, v. Koenen.
Chonetes Laguessiana, De Kon.
Leptæna analoga, Phill.
Orthotetes crenistria, (Phill.).
Spirifer, sp.
Athyris, sp.
Goniatites (*Prolecanites*) *mixolobus*, Phill.
Goniatites (*Prolecanites*), sp.
Goniatites (*Nomismoceras*) *spirorbis*, Phill.
Goniatites (*Pericyclus*), sp.

In his *Sketch of the Geology of Devonshire*, page 9, Mr. Townshend Hall says the Codden Hill beds are succeeded by "beds of hard grits, alternating with slates and shales forming a series of anticlinals and synclinals with contortions in every possible direction. The coast-line in general presents a splendid series of cliffs, those near Clovelly and Hartland Point being especially remarkable, not only for their height, but also for the manner in which the beds have been dislocated, crumpled up, overturned, and contorted," also, "several intermittent beds of anthracite, or culm as it is locally called, traverse the millstone grit from Greenacliff, near Bideford, to Umberleigh Station, and sufficient fuel was formerly raised in this locality to burn the limestone brought from South Wales. The adjoining slates are in many places almost vertical, but there are also several anticlinals. A hard, quartziferous sandstone almost approaching a quartzite occurs near an outcrop of a vein containing iron ore and manganese at Greenacliff, and on the south of it the nests or bunches of anthracite afford good specimens of *Pecopteris*, *Calamites*, and *Lepidodendron*. At Pitt Quarry, in the parish of Abbotsham, a great variety of characteristic plants, including the rare *Bowmanites*, or fruit of the calamite, have been found in the grits adjoining the culm bands." The Culm Measures have also been described in detail, and some of the boundary lines corrected by Mr. Ussher.*

* See Ussher, *Proc. Somerset Archæol. and Nat. Hist. Soc.*, vol. xxv (1879) p. 1; and vol. xxxviii (1892), p. 111.

VIII.—SUMMARY.

The Morte series contain evidently the oldest rocks in North Devon and West Somerset. In them are beds which, by their fossils, indicate an horizon low down in the Silurian (Upper Silurian of Survey), and in some of the areas there seem to be passage beds between Silurian and Lower Devonian. The beds in contact with these, either as the result of uncomformity, or from the effects of faults on the north side, are Hangman grits, Combe Martin, or Ilfracombe beds, and on the south side Pickwell Down sandstones. Though it will be well, until the fauna has been thoroughly worked out, not to attempt a correlation of the Devonian rocks found in the several districts with each other, or with those found in other areas, it may not be out of place to draw attention to the marked similarity in the deposits which occur north and south of the Morte Slates. Similar grits and sandstones, with plant and fish remains, occur in each case at the base of the series; next come flaggy sandstones and shales, with large lamellibranchs as their most characteristic fossils, and these are succeeded by muddy and calcareous beds, full of brachiopods, and in places with corals. That there are many species also in common in both series is certain, and I feel confident that a larger number would, ere this, have been made out, were it not for the highly-altered condition of some of the beds in the greatly-crushed and folded trough on the north side of the Morte Slates. The thicknesses usually given have been greatly exaggerated, and the folding is more general and intense. Faults also are frequent, and being usually in the line of the bedding, beds of varying horizons have been frequently brought together within a small space.

With regard to the horizon of the Codden Hill (carboniferous) beds, Messrs. Hinde and Fox say (p. 662): "The additional fossils (excluding radiolaria) which we have found in the Radiolarian Beds tend to confirm the view that these and the Lower *Posidonomya* and Waddon Barton Beds are the representatives and equivalents of the Carboniferous Limestone in other portions of the British Isles; not, however, in the at present generally understood sense that they are a shallow-water facies of the presumed deeper-water Carboniferous Limestones, but altogether the reverse; that they are the deep-water representatives of the shallower-formed calcareous deposits to the north of them."* The passage from the Devonian to the Carboniferous in North Devon seems to be a gradual one, and there does not appear to be any sign of a break between them. If this is the case, there is a marked general resemblance between the succession

* Mr. H. B. Woodward is disposed to regard these Codden Hill beds as not older than the Yoredale Rocks (*see* Discussion on Dr. Hicks' paper on Morte Slates, etc., *Quart. Journ. Geol. Soc.*, vol. lii, p. 272).

here and that on the opposite side of the Bristol Channel, in South Pembrokeshire. There some of the beds between the old red sandstone and the mountain limestone resemble in many ways the Baggy and Pilton Beds, and I may just mention in passing that Mr. Whidborne and I, when working out the zones there, found fossils usually considered characteristic of the Devonian rocks. An interesting point to be yet decided is as to how much of the Lower Limestone Shale Series in South Wales should be classed as Devonian, and how much as Carboniferous ?

(For References, see p. 387.)

A PRELIMINARY SYNOPSIS OF THE FAUNA OF THE PICKWELL DOWN, BAGGY, AND PILTON BEDS.

By the REV. G. F. WHIDBORNE, M.A., F.G.S.

Pickwell Down Sandstone.

Fish Remains and Wood, collected by Dr. Hicks, F.R.S., and myself.

Marwood, Baggy, and Sloly Beds.

Arthropoda.

Cariderpestes gyius, n. sp., a Myriopod with very long body, narrow spine-less plates, and elongate appendages.
Echinocaris Whidbornei, Jones & Woodward.
Anatifopsis (?) *Anglica*, n. sp., like *A. acuta* Barr., but shorter.
Ceratiocaris (?) sp., small, oval valves.

Cephalopoda.

Poterioceras, sp. (= *Orthoceras imbricatum*, Phill. not His.).
Orthoceras vennense, Foord.
Actinoceras (?) (*Huronia*) *Crickii*, n. sp., with longitudinally striated surface, rather narrow chambers, and siphuncle arranged as in *Huronia*.

Gasteropoda.

Naticopsis Hallii, n. sp., sub-globose, oblique, very like *N. striolata*, F. A. Römer, but smooth.
Bellerophon subglobatus, McCoy.

Lamellibranchiata.

Leptodomus constricta, McCoy.
L. semisulcata, Sow.
Sanguinolites mimus, n. sp.
Prothyris scalprata, n. sp., flat, lancet-shaped, sub-angular behind, with large anterior notch.
Myophoria deltoidea (Phill.).
Ctenodonta pullastræformis, McCoy.
Ct. tensa, n. sp., very transverse, acute behind, with fine and very irregular growth lines.
Cypricardinia, sp., with numerous step-like ridges.
Cucullæa unilateralis, Sow. (including varieties, *Hardingii*, *amygdaloides*, *angusta*, *and trapezium*).
C. depressa, Phill.

Ptychopteria damnoniensis (Sow.).
Actinopteria rudis (Phill.).

Brachiopoda.

Lingula squamiformis, Phill.

Plants.

"*Knorria*," sp.
"*Bernia*," sp.
"*Rhodea moravica*" (?), Stigmarian roots.
Fucoids.

Pilton, Croyde, and Braunton Beds.

Vertebrata.

Fish scales.

Arthropoda.

Ceratiocaris (?) *subquadrata*, n. sp., large sub-oblong valves with ogee end.
Phacops latifrons (Bronn.).
Phillipsia Hicksii, n. sp., with a tuberculated pygidium of thirteen rings with a broad rim.
Brachymetopus Woodwardii, n. sp., differing from *B. Maccoyii* (Portlock) by having a larger glabella and fewer rings in the tail.
Isochilina canaliculata, Krause.
Aparchites Lindstrœmi, Jones, var.
Primitia sparsinodosa, n. sp., differing from *P. mundula*, Jones, in bearing tubercles.
Primitia, 2 sp.
P. dorsicornis (Ulrich).
P. bovifrons, n. sp., large sub-oblong valves, with margined central furrow and long horns in the upper corners.
P. vestita, n. sp., bean-shaped, with a central node and rugose surface.
Beyrichia æquilatera, Hall (?).
B. Damesii, Krause (?).
Beyrichiopsis Ruperti, n. sp., smaller than *B. fimbriata*, Jones and Kirkby, and without a central boss.
Klædenia bursæformis, n. sp., sub-ovate, with three elevated lobes and narrow rim.
Ulrichia interserta, n. sp., with two large oval defined central nodes and elevated ends.

Cephalopoda.

Agoniatites, sp.
Goniatites, sp., small globose.

Subclymenia Symondsii, n. sp., differing from *S. evoluta* (Phill.) by being tuberculate.
Poterioceras, sp.
Orthoceras, sp. (=*O. Ludense*, Phill. not Sow.).
Orthoceras, sp.
O. speciosum, Münster.
O. Barumense, n. sp., very like *O. ibex*, Sow., but without longitudinal striæ.

Pteropoda (?).

Conularia deflexicosta, Sandb.
Tentaculites conicus, F. A. Römer.
T. tentacularis (Phillips).

Gasteropoda.

Macrochilina turbinea, n. sp., like *M. elevata*, Whidb., but with broader whorls and turbinate spire.
M. pusilla, n. sp., minute, approaching *M. minor*, De Kon., but with a wider body-whorl.
Loxonema Hallii, n. sp., approaching *L. leviusculum*, De Kon, but with fewer and broader whorls.
L. trochleatum (Münster).
L. priscum (Münster).
L. Anglicum, D'Orb. (=*L. rugifera*, Phill., Pal. Foss., not Geol. Yorks.).
Natica meridionalis, Phill.
Capulus rostratus, Trenkner (?).
C. terminalis, Whidb.
C. compressus, Goldf.
Orthonychia rotunda, n. sp., slightly plicated, semi-elliptic, with recurved sub-central apex.
O. acuta (F. A. Römer).
Holopella tenuisulcata, Sandb.
Aclisina longissima, n. sp., aciculate, with six spiral equidistant threads.
Euomphalus vermis, n. sp. (=Phill., Pal. Foss., Pl. 36, fig. 172c—e).
Euomphalus, sp.
Rhaphistoma junius, De Kon.
Pleurotomaria gracilis, Phill.
Pl. Hamlingii, n. sp. (=*Pl. aspera*, Phill., Pal. Foss., Pl. 37, fig. 117a, b).
Pl. aspera, Sow.
Murchisonia Anglica, D'Orb. (=*M. angulata*, Phill., Pal. Foss., not Geol. Yorks.)

Murchisonia, sp.
M. similis, Trenkner.
Bellerophon labyrinthodes, n. sp., approaching *B. Hicksii*, Whidb., but with finer and zigzagging ornament.
B. macromphalus, F. A. Römer.
B. elegans, D'Orb.
Bellerophon (?), sp.
Tropidodiscus trilobatus (Sow.).
Euphemus Barumensis, n. sp. (=Phill., Pal. Foss., Pl. 40, fig. 199).

Lamellibranchiata.

Leptodomus constricta, McCoy.
Panenka Anglica, n. sp., smaller and with finer ribs than *P. grandis*, Whiteaves.
Sanguinolites Porteri, n. sp., transverse, slightly keeled, covered with fine, regular ridges.
S. mimus, n. sp., similar, but with smooth posterior slope and fewer ridges.
Edmondia Bodana (F. A. Römer).
E. Athenæ, n. sp., small, short, oval, with few strong ridges.
E. Hamlingii, n. sp., globose, nearly smooth, with sub-central umbo.
Sphenotis (?) Hicksii, n. sp. (=*Pullastra (?) complanata*, Phill., not Sow.).
Sph. solenoides, Hall (?).
Sph. (?) soleniformis (Goldfuss).
Phthonia, sp.
Prothyris recta, n. sp., small, sub-oblong, coarsely striated.
P. contorta, n. sp., elongate, finely striated, with sigmoidal lower margin.
Scaldia (?) longa, n. sp., small, smooth (?), transversely ovate, with sub-central umbo.
Cypricardinia scalaris (Phill.).
Myophoria trigona (F. A. Römer).
Modiolopsis, sp.
Nucula lineata, Phill.
Ctenodonta Newtonii, n. sp.
Nuculites latissimus (Phill.) ?
Ctenodonta lirata (Phill.).
C. (?) *elliptica* (Phill.).
Koenenia, sp.
Parallelodon pygmæus, Whiteaves, var. *infans*.
P. priscus (Goldfuss).
Modiola amygdalina, Phill.
Spathella munda, n. sp., obliquely transverse, sub-trigonal, covered with fine regular transverse striæ, and with sub-anterior umbo, which is regularly pitted within.

Mytilarca modioloides, n. sp., obliquely sub-trigonal with anterior umbo and steep front margin.

Cobracephalus angulosus, n. sp., oblique, semi-globose, radially angulated, crossed by fine sharp striæ, with incurved umbo and large angulated front wing.

Leptodesma citimum, n. sp., smooth, short, trigonal, oblique with very large wings and sub-anterior umbo.

L. cultellatum, n. sp., very transverse, sabre-shaped, finely striated, with short hinge and wings.

L. anatinum, n. sp., transversely sub-oblong with large umbo and wings and coarse growth striæ.

Leiopteria Conradi, Hall.

L. murata, n. sp., sub-ovoid, slightly transverse, with large hind wing and few strong regular concentric ribs.

Ptychopteria Damnoniensis (Sow.).

Pterinopecten Hallii, n. sp., short sub-orbicular with 20 or 30 strong distant alternating ribs and fine distant transverse threads.

Pt. mundus, n. sp., similar, but with simple ribs and close striæ.

Pt. scabriradians, n. sp., right valve with strongly rugose rays and very long narrow triangular wing.

Pt. polytrichus (Phill.).

Pt. Austeni (F. A. Römer).

Actinopteria rudis (Phill.).

Aviculopecten transversus (Sow.).

A. nexilis (Sow.).

Pleuronectites Piltonensis, n. sp., smooth, with striated wing and produced anterior side.

Pl. lepis, n. sp., smooth, sub-orbicular, slightly oblique, with sub-equal wings.

Pl. Hicksii, n. sp., short, ovate with minute concentric striæ.

Crenipecten auritus, n. sp., very short, radiated, with small central umbo and large sub-equal wings.

Pernopecten (?) insperatum, n. sp., flat, sub-orbicular, with gently protruding rounded wings.

Brachiopoda.

Tropidoleptus carinatus (Conrad).

Athyris (?) oblonga (Sow.).

A. (?) concentrica (Von Buch).

A. rugulosa, n. sp., large, with wide flattened fold and numerous imbricated foliaceous striæ.

Spirifer Urii, Fleming.

Sp. lineata (Martin).

Sp. Verneuilii, Murchison.

Sp. obliterata, Phill.
Spiriferina cristata (Sow.), var. *octoplicata*, Dav.
Rhynchonella laticosta (Phill.).
Rh. Partridgii, n. sp. (= *Rh. pleurodon*, Phill., Pal. Foss.).
Camarella togata, n. sp., with three large ribs on fold.
Orthis interlineata (Sow.).
Strophomena rhomboidalis (Wilckens).
Orthotetes crenistria (Phill.).
Productus prœlongus (Sow.).
P. longispinus, Sow.
P. tenuistriatus, De Vern.
Strophalosia productoides (Murch.).
Chonetes Hardrensis, Phill.
Chonetes margaritacea, n. sp., differing from *Ch. Phillipsii*, Dav. in being wider and having finer striæ.
Ch. Illinoisensis, Worthen.
Discina nitida, Phill.
Lingula squamiformis, Phill.
Craniella Medusinensis, Œhlert.
Crania ringens, n. sp., transversely oval, with large muscle-scars situated very posteriorly.

Polyzoa.

Fenestella plebeia, McCoy.
F. laxa, Phill. (?).
Penniretipora bipinnata (Phill.).
Rhabdomeson gracilis (Phill.).
Rh. (?) distans, n. sp., dichotomizing witth fewer and more distant zoœcia, with oval apertures.
Streblotrypa Gregorii, n. sp., stems with acute, narrow, undulating ridges dividing large zoœcia, which are separated transversely by three or four large mesopores.
Berenicea irregularis, Lonsdale (?).

Echinodermata.

Lepidesthes (?) devonicans, n. sp., with about seven rows of small plates in each area, the IA plates having about five warts and small spines.
Eocidaris (?) acuaria, n. sp., having long striated spines, and plates with a large central and minute scattered tubercles.
Palæaster longimanus, n. sp., with large irregular warts on body and seven rows of plates on arms.

Eugaster granifer, n. sp., with minutely granulated surface, circular disk, and two alternating rows of very narrow central and two of lateral ossicula and short petaloid spines.

Protaster scabrosus, n. sp., with pentagonal coarsely plated disk and small aciculate spines.

P. gregarius, n. sp., with small petaloid disk and long narrow broad-plated arms.

P. perarmatus, n. sp., large, with stout blunt arms and long spines.

Adelocrinus hystrix, Phill.

Actinocrinus Porteri, n. sp., large calix with fine stellate ornament and very numerous arms, IBr. in thirteen rows.

A. (?) *Batheri*, n. sp., with small shallow calix ornamented with strong tessellated bars, arms immediately dividing into twenty.

Taxocrinus macrodactylus (Phill.).

Taxocrinus (?) *stultus*, n. sp., with 3 B, 5 R and intercalated anal, and with IBr. in three rows.

Cyathocrinus, sp.

C. Barumensis, with small globose shallow cup, five wide inversely pentagonal RR and first IBr. elongate, axillary.

Poteriocrinus stadiodactylus, n. sp., BB 5 short, with very long thin arms composed of very elongate Brr.

P. Batheri, n. sp., cup elongate with five small pentagonal IBB, five large elongate hexagonal BB with 2nd IBr. axillary.

P. tensus, n. sp., calix with five hexagonal wide BB, arms long, rarely branching, with 5th IBr. axillary, and anal tube extremely elongate.

Annelida.

Cornulites devonianus, n. sp., small, elongate, conical, slightly flexuous, with few step-like annuli.

Actinozoa.

Cladochonus cornucopiæ, n. sp., with cups larger than *C. Schlüteri*, Holz., and strongly ridged within.

Petraia pauciradialis, Phill.

P. pluriradialis, Phill.

Cyathophyllum, sp.

Amplexus tortuosus, Phill. (?).

Michelinia antiqua, McCoy.

Pleurodictyum repens, n. sp., differing from *P. problematicum*, Phill., by forming irregular, elongate, and sometimes ramose, masses.

NOTE.—The Rev. G. F. Whidborne is at present describing the above species in a Monograph of the Palæontographical Society, and will be very grateful to be allowed to examine any characteristic specimens that may throw fresh light on the fauna of these beds.

NOTES ON THE TRIAS, RHÆTIC, AND LIAS OF WEST SOMERSET.

BY THE REV. H. H. WINWOOD, M.A., F.G.S.

[*Read 3rd July, 1896.*]

I HAVE been asked to give a few notes on the New Red and Lias in that portion of the district which we shall visit on the first two days of the long Excursion in July. The route followed will be from Bridgwater to Watchet, skirting the east side of the Quantock Hills, and then along the valley between those hills and the Brendons to Taunton, and is included in sheet 20 of the Geological Survey Map. There are not any sections, probably, in the West of England showing more interesting exposures of the Lower Secondary Rocks than these in question. I need only refer to the writings of Prof. Boyd Dawkins, Messrs. Etheridge, Woodward, and Ussher, in confirmation of this—and it is to these workers in the field that I am indebted for a large portion of these notes. It is not my province to describe the Palæozoic rocks of this district, but to understand its physical features we must picture to ourselves the Devonian rocks of the Quantocks and the Brendon Hills, standing up more or less in their present position as islands, against which the waters of Triassic times washed, depositing their burden of silt, sand, and gravel in the deeper valleys and shallower creeks running up into their recesses. One is reminded of similar conditions prevailing at the time that the Dolomitic conglomerate was laid down around the Mendip Hills. In both cases the denudation must have been very great; the results in the latter consisting of Old Red Sandstone and Carboniferous Limestone, in the former of the Grits, Sandstones, and Limestones of the Devonian series. The best exposures of these Triassic rocks will be visited on Tuesday in the Stogumber Valley, between Williton and Sampford Brett; but owing to the many complicated faults, it will be almost impossible to give any detailed description (see Fig. 1). When the patient labours of Mr. Ussher appear in the new one-inch map these will be all worked out in detail. It must suffice to state that he gives the following order of succession:

Trias	Keuper or Upper Trias	Upper	Marls, Marginal Sands, and Breccias.
		Lower	Sandstones, local intercalation, with Marl at base.
			Conglomerate, Breccia, Gravel.
	Middle Trias		Marl.
			Sandstone (local) at base.
	Lower Trias		Breccio-conglomerate and Breccia.
			Sand, more or less brecciated in places.

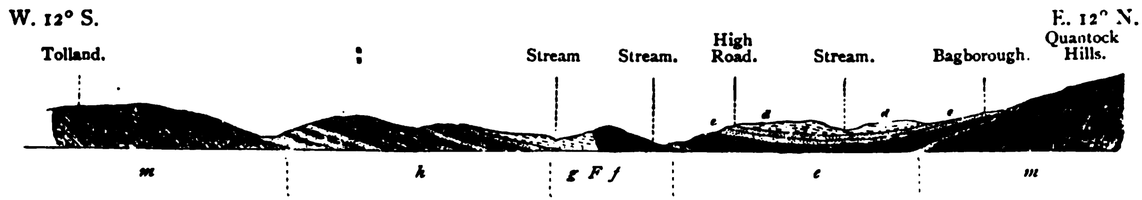

FIG. 1.—SECTION ACROSS THE VALLEY BETWEEN THE QUANTOCK AND BRENDON HILLS.—*W. A. E. Ussher.*

Length of section about 4½ miles.

d Triassic Upper Marls.	*g* Triassic Lower Marls.
e ,, Upper Sandstones.	*h* ,, Lower Sandstones with Breccia.
f ,, Pebble Beds and Conglomerate.	*m* Devonian Grits and Shales.

F Fault.

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After these preliminary remarks on the general features of the district to be visited during the two days that I am to have the pleasure of being your director, let me describe what we shall see on our first day (Monday). Leaving the alluvial flats of Bridgwater, celebrated for the manufacture of the well-known "Bath bricks," we shall drive over the New Red marls of Wembdon Hill to the village of Cannington, about half a mile from which is the celebrated patch of Limestone at Cannington Park. Opinions have been much divided as to the age of this Limestone, and for some time the pendulum swung between Devonian and Carboniferous. Lithologically the disturbed highly crystalline beds dipping at about 27° S.S.W. put on now a Carboniferous, now a Devonian aspect; but the list of fossils given by Mr. H. Cossham* is pronounced as decidedly Carboniferous on the authority of Mr. Etheridge. The dense character of the rock renders it difficult to get good specimens; during a recent visit there, in a dark-blue bed about 2 ft. 6 in. thick at the western corner, many sections of brachiopods and turbinate corals could be seen. The specimens, however, which I forwarded to Mr. E. T. Newton were so poor that he could only hesitatingly name them as *Capulus*, *Athyris*, *Productus*, *Bellerophon*, and a Turbinate coral, at the same time adding that he did not think there was any room for doubting their Carboniferous age. During my visit instructions were given to the workmen to preserve all they found for your inspection, so that you may have an opportunity of forming your own opinion on this question.

Resuming our drive we pass over the Keuper Marls and Sandstones which fringe the eastern base of the Quantocks, running into the little coves and round the promontories of that ancient land, in the same manner (as De la Beche writes) that the alluvial flats near Bridgwater run into coves and round promontories formed of these red deposits themselves, and turn off to the left to Adscombe, S.E. of Over Stowey. A good section here shows Middle Devonian limestones and slates faulted against the usual grits† of these hills. At the junction a compact fragmentary rock occurs, considered by Mr. Rutley to be a Volcanic Ash. The beds of dark-blue dense Limestone show numerous corals on their weathered surfaces, but other fossils seem scarce. A dip taken on the greasy mottled slates gave 30° N.N.E.

Descending to Nether Stowey and taking the high road to Holford, we leave the copper mines at Doddington, formerly worked in the Keuper Marls, on the right (there is an outcrop of Devonian Limestone here, but it is hardly worth visiting), and pass through some charming woodland glades, the haunts of Wordsworth and Coleridge when living at Alfoxden, to the village of

* *Proc. Cotteswold Naturalists' Field Club*, vol. viii, p. 20.
† Ussher considers these grits to be equivalent to the Hangman grits.

Holford. A good section on the left before reaching the Plough Hotel shows the usual reddish-grey Devonian grits.* Intercalated bands of rotten earth contain encrinital impressions, but so badly preserved that they are difficult to recognise. On a former occasion when I visited this section (Woodlands quarry) the following note occurs: "The bottom beds, which have been worked down somewhat below the level of the road, are close-grained purplish-grey sandstones, with greenish-coloured marly partings; in these traces of plants occur. Succeeding them in ascending order is a series of thicker beds of a dense siliceous texture of a lighter grey colour, also very fissile. In the middle of a section made in these beds, close to the road side, about 5 ft. in depth, in a thin rotten band, occurs abundance of encrinital plates, casts of Brachiopods, *Tentaculites* and Corals. At the back of the quarry, which had then been worked down some 20 ft. or 30 ft., about half-way up in an almost black arenaceous band (drying red), was a similar series of fossils to those below." Should time permit another section ought to be visited. It lies to N.W. of Woodlands quarry, and nearly opposite the gate leading to Alfoxden. Here some mottled, coarse-grained siliceous sandstones, reminding one of the Hangman grit series, contain casts of a gasteropod (probably a *Natica*) and *Petraia*.

Returning to the main road, we come to Putsham, on the Keuper sandstone, and, if possible, make a *détour* of a mile to the Lower Lias, *Bucklandi*-beds, which form the coast-line at Kilve Pill, and dip landwards; numerous characteristic fossils can be obtained on the foreshore. The only other feature of interest to detain us before reaching St. Audries is the Perry quarry at the left-hand side of the road, a short distance this side of the Stowey or Fairfield Lodge, consisting of similar compact grey and purple sandstones, dipping about 30° N.E., becoming more fissile and micaceous in the upper beds.

We now leave the N.W. prolongation of these older rocks, and turn aside to visit the coast sections. A drive of about a mile, by the kind permission of Sir A. Acland-Hood, through his picturesque deer-park, takes us to "St. Audries Slip," a private road leading down to the shore. After enjoying the fine view from the edge of the cliffs we descend to the beach, and have before us probably one of the finest exposures of Keuper Marls, Rhætic, and Lower Lias to be seen in one continuous section in the West of England. To the east of the Slip onwards to Quantockshead is one successive series of the New Red Marls; a fault then brings down the Lower Lias beds against the former, conspicuous in the distance by the change of colour in the cliffs. The road passes over the upper beds of the New Red, and to the west we see a conformable sequence of New Red Marls, Rhætic,

* *Proc. Bath. Nat. Hist. and Antiq. Field Club.* Vol. ii, 1870-73, p. 430.

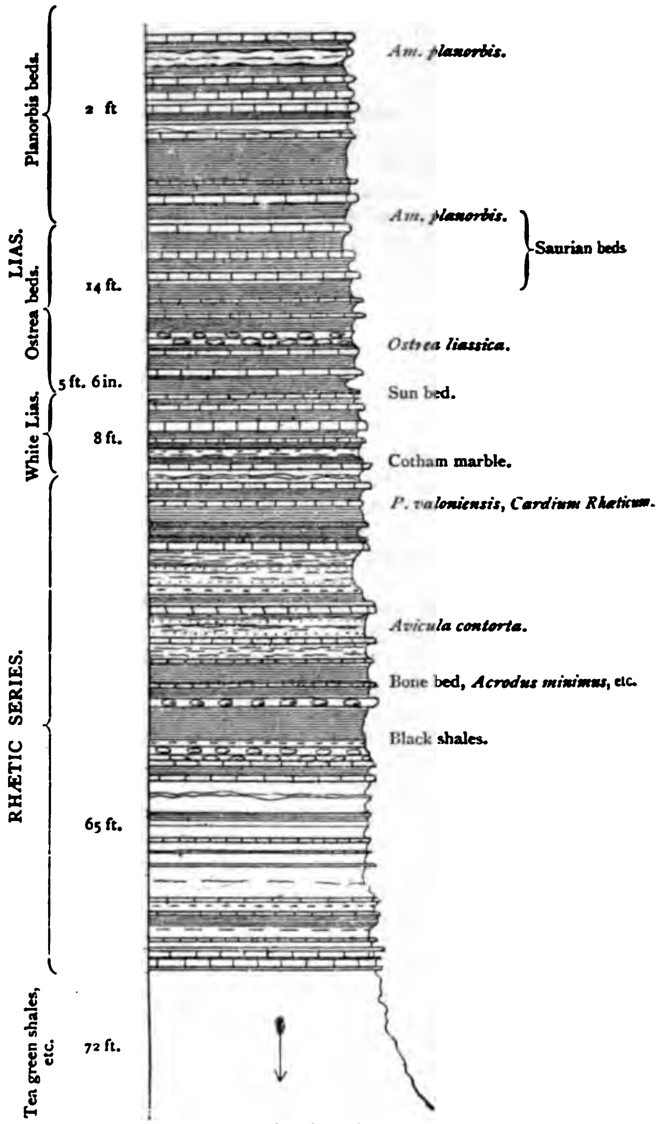

FIG. 2.—SECTION OF THE RHÆTIC, OSTREA, AND PLANORBIS BEDS AT ST. AUDRIES SLIP, EAST OF WATCHET.—*R. Etheridge.*

and Lower Lias dipping uniformly to the S.W., thick beds of Lower Lias limestones forming the western horn of the bay. The blue limestone bed, 18 in. thick, resting immediately on the beach, dips 15° S.W.

The entire thickness of the beds exposed, as measured at right angles to their dip by Mr. Etheridge, some years ago, is 250 ft. At the base are alternating grey, green, red, and pale yellow bands of hard and soft Marls (called "tea-green" marls) to a thickness of 72 ft. Above these come about 66 ft. of grey, brown, and black shales, with bands of argillaceous limestone —the Rhætic series. Then follow the White Lias and *Ostrea* beds, about 28 ft. in all; and then 24 ft. of *Planorbis* beds. Finally the *Bucklandi* and *Lima* series which rest upon these are estimated as from 50 ft. to 70 ft. in thickness. Further details are given in the section opposite (Fig. 2).

The upper portion of the shales (26 ft.) between the White Lias and the Bone bed is rich in organic remains. The fossil-hunter will have an opportunity of collecting most of the Rhætic forms from the blocks lying on the shore, and from the reefs which sweep in graceful curves seawards. The fossiliferous Rhætic beds strike the beach about midway, and the reefs of alternating limestone bands and black shale run out seawards, and abound in *Pleurophorus elongatus* and other fossils. A land-slip has brought down the *Pecten valoniensis* and *Avicula contorta* shale at this spot. The characteristic Ammonite of the *Planorbis* beds abounds, together with *Ostrea liassica*, and the following Rhætic forms may be obtained: *Avicula contorta*, *Pecten valoniensis*, *Cardium Rhæticum*, *Pullastra arenicola*, *Pleurophorus elongatus*, *P. angulatus*, *Lima præcursor*, *Myacites*, *Modiola minima*, teeth of *Saurichthys*, *Sargodon Tomicus*, *Hybodus*, etc.

On Tuesday, an early start by train from Taunton will enable the members to reach Williton in time to visit some of the sections of the New Red rocks in that district. It will be impossible in these notes to give any minute account of the various divisions of the Trias so carefully worked out by Mr. Ussher; for that purpose his various papers quoted in the References (p. 387) must be consulted. It would take many a traverse in the Stogumber Valley to trace the complicated faults of this district that render the relations of Marls, Sandstones, and Conglomerates so very obscure. When Mr. Ussher, who has kindly supplied me with a few notes, writes, "It is unquestionably the toughest piece of New Red work I know of," we must be content to accept this dictum, and merely see all we can in a hasty visit. Leaving the train, then, at Williton Station, we take the road to Sampford Brett. Passing through the town of Williton, which is on a River-gravel flat, the first exposure seen is on the hill to the west. On the right-hand side of

the road, just beyond some newly-erected houses, is a quarry, worked for building-purposes, showing, according to Mr. Ussher, the Marls and Sandstones of the Keuper or Upper Trias. The lowest bed exposed is a rather close-grained, quartzose, speckled sandstone (Keuper sandstone), succeeded by beds of Conglomerate more or less coarse, with marly beds intercalated. Towards the top of the hill the sandstones are much softer. Descending the hill to the railway, east of the village of Sampford Brett, and crossing the line to the opposite bank, a very fine section of Conglomerate is seen, forming the base of the Upper Trias. This section, about 15 ft. in depth, consists of very coarse Conglomerate, with finer beds intervening. A Breccia comes in near the top composed of angular and sub-angular *débris*, some of it mere splinters. The pebbles of the Conglomerate are coarser towards the base, and consist of purplish sandstone, quartzite of various colours (white and pinkish), large and small pebbles of a dark blue or black hornstone or Lydian stone, etc. The beds in the upper section dip, at an angle of 23°, towards the cutting, where they are exposed again to a depth of about 30 ft.

Returning, and taking the train at Williton, we pass through Watchet to Blue Anchor Station, noting just as we leave Watchet, in the railway cutting north of St. Decuman's church, a fine section of Rhætic beds, exposed to a depth of 75 ft. by the great east and west St. Decuman's fault. Leaving the train at Blue Anchor Station, we follow the flat shore-line to the rising ground on the east. The first half-mile has not any feature of interest except the indications of damage done by the coincidence of a N.W. wind and high tide during a recent November gale. At the back of the inn situated on the top of the cliff, a field is strewn with quartzite pebbles, which are turned up abundantly by the plough in the lands adjoining. Descending to the shore just below the cottages, we pass under the Red beds of Keuper Marl to Blue Anchor Point, where the pink and grey Alabaster beds first appear. Large masses fallen from the cliffs above picturesquely jut out on the beach, presenting good examples of the way in which the pink and white Gypsum occurs in beds and reticulated veins. This place, perhaps, exhibits the prettiest example of the latter in the whole coast-line. Turning the point, we come to the workings high up on the cliff, and possibly a schooner may be seen stranded between the reefs, loading with the mineral for Swansea or the paper-works at Watchet. The white variety is the most valuable for that purpose. About one mile beyond the point we come to the place rendered classical by the discovery of a tooth of the earliest known mammal, *Microlestes* (*Hypsiprymnopsis*) *Rhæticus*, by Professor Boyd Dawkins, in 1864.* The beds here have been much disturbed by slips and

* During the recent visit of the British Association to Oxford, I looked in vain for this molar tooth to the Oxford Museum, where it had been deposited by the discoverer.

faults, which render their true succession rather puzzling, but at the same time very interesting to work out. Two main faults are the key to the geology of this part. One runs west of Watchet harbour, nearly parallel with the coast line, and disappears seawards at Blue Anchor. By this the Lower Lias (*Am. planorbis*) beds are thrown down to the south. The other, taking the same course, runs farther out near low-water mark, bringing the *Am. planorbis* beds down to the north. So that you get the beds in the cliff on the south again repeated on the foreshore on the north (Fig. 3). A little west of Chapel Cliff—so called from a Chapel which once existed on the Cliff—or "Grey Rock," as the workmen now name it, from the masses of Grey Marls and Lias rock which stand upon the shore, the collector may revel in fossils. Whether in the blocks strewn along the beach, or in the reefs which dip away seawards, fossils abound. Conspicuous on the large, grey slabs are the *Am. planorbis* * and *Am. Johnstoni*, the former nacrously iridescent, some as large as 6 in., many 2 in. and 3 in. in diameter. Enthusiastic hammerers may here try the reefs in succession for another mammal tooth. Taking Prof. Boyd Dawkins' section as their guide, they will start from soft, slate-coloured marl, black at base of cliff 4 ft., then come to dark-grey and black slaty beds containing flesh-coloured and white fibrous gypsum 4 ft., then dark, slate-coloured marlstone with flesh-coloured gypsum 4 ft., then coal-black shale, a marked feature, also containing gypsum 10 ft., then indurated gypseous, grey sandy marls 10 ft.; the grey, ripple-marked fissile sandy marlstone (6 ft. thick) next above this is very fossiliferous: *Modiola minima*, *Pecten valoniensis*, *Gervillia præcursor*, *Pullastra arenicola* (with their shells), *Cardium Rhæticum*, &c., and fish teeth. It was in this bed that the celebrated tooth was found, but owing to the wearing away of the cliff since then, the distance of this grey fissile bed from the soft, slate-coloured marl (*i.e.*, 32 ft.) may be considerably increased. If the tide be sufficiently low, a mass of Lias limestone, called, "Tor Point," from which I was informed many hundred tons of stone had been taken for burning, may be seen; otherwise, the farthest rocks visible seawards are the Red and Grey Keuper Marls. At the base of the cliffs at this point a landslip has brought down a mass of Lower Lias and Rhætic beds, the grey fissile slabs of the former containing *Am. planorbis* and *Am. Johnstoni*; numerous bivalves and fragments of the bone-bed also occur.

Passing eastwards, the Red beds with gypsum set in with numerous step faults. About midway comes the great north and south Warren fault, causing a great disturbance in the cliffs at this point, and wedging in the Lower Lias and Rhætic series in a V-shaped mass. After passing the boundary stones marking the

* Now called *Ægoceras planorbis*. The original of Sowerby's two figures came from Watchet.

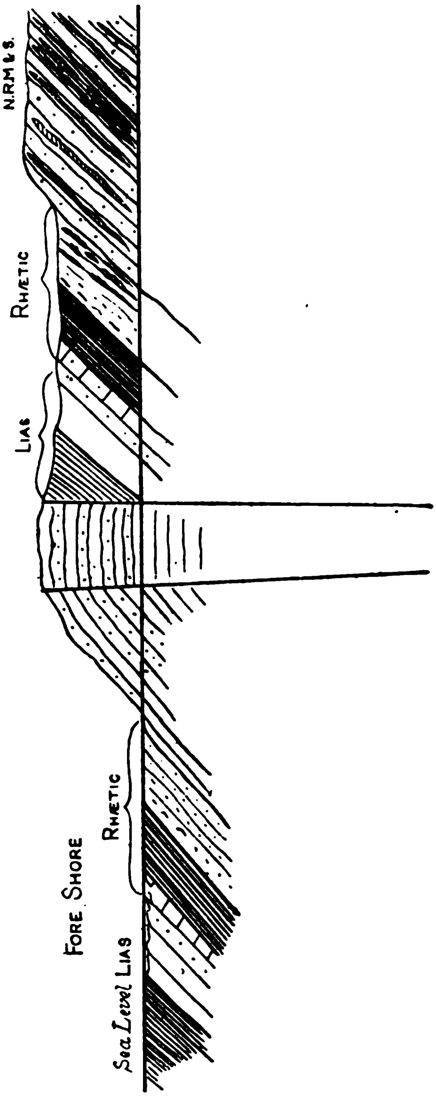

Fig. 3.—Section West of Watchet.—*R. Etheridge.*

Figs. 2 and 3 are reproduced by the kind permission of R. Etheridge, F.R.S. L. and E., F G.S., etc.

division of property between Mr. Luttrell's on the west and Lady Egremont's on the east, there is a good example of a fault having been subsequently filled in by a vein of Gypsum. The Red Marls capped with Grey beds continue onwards to Watchet. Should time permit the section east of Watchet can be visited before taking train to Taunton.

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"PEBBLY GRAVEL" FROM GORING GAP TO THE NORFOLK COAST.

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[*Read 6th March*, 1896.]

I.—INTRODUCTION.

THE term "Pebbly Gravel" has been applied by the officers of the Geological Survey to a series of gravels, occurring chiefly in East Anglia, which are characterised by the presence of quartz and other foreign pebbles in addition to those of flint.

The clearest and best account of these beds, as a whole, is that given by the late Sir Joseph Prestwich as the result of his fifty years' intermittent work upon them. He refers nearly the whole of them to his Westleton Series, since they are well developed near the East Suffolk village of that name, and he regards them as of marine origin.*

Before this Association also, papers have been read by Messrs. Monckton and Herries† and Osborne White‡ dealing with portions of these beds to the north of the Thames and round Henley respectively.

Mr. Whitaker and other officers of the Geological Survey have also described these gravels in the Memoirs written by them on the various districts of East Anglia.

I have made full use of these and other papers, and beg to thank the writers for their valuable information.

In the present paper numerous gravel deposits at high levels (300 ft. to 650 ft.) in the Thames Valley will be first considered. Then the connection, if any, between them and various gravels and sands of East Anglia will be discussed. Lastly, I will submit a few deductions regarding the mode of origin of some or all of these deposits.

II.—HIGH LEVEL GRAVELS OF THAMES VALLEY.

Palæontological evidence being entirely absent, the constitution and heights of the various deposits have to be taken advantage of. I intend to classify them according to the former, and then draw conclusions with regard to the latter. By this means, the necessity of describing a large number of sections will be obviated. I shall present them to you in groups, taking some section near London as a type, at the same time stating any distinguishing feature particularly, and giving new sections in greater detail.

* *Quart. Journ. Geol. Soc.*, vol. xlvi (1890), p. 84.
† *Proc. Geol. Assoc.*, vol. xii (1891), p. 108.
‡ *Proc. Geol. Assoc.*, vol. xii (1892), p. 379, and vol. xiv (1895), p. 11.

The whole of the high level gravels examined by me—and I examined all I heard of—belong to one or other of the five groups A—E, which I will now proceed to describe:

A.—Barnet Gate Type.

This series includes simple ochreous gravels, occupying some of the highest ground in Bucks, Middlesex, South Essex, and North Kent. The localities examined were:

		Height. ft.	Depth of deposit. ft.
1.	Tyler's Hill, near Chesham	600	3
2.	Tyler's Common, near Penn	580	6
3.	Stanmore Common, Middlesex	500	7
4.	Harrow Weald	480	7
5.	Barnet Gate, one mile west of High Barnet	465	7
6.	Shooter's Hill, Kent	424	10
7.	Newgate Street, N.E. Middlesex	322	6
8.	Norton Heath, four miles east of Ongar	314	(?)
9.	Billericay, half-mile north of station	319	8
10.	Brentwood, just north of station	300	5
11.	Langtons, South Weald Park	300	4 to 5
12.	Warley, north of Holden's Wood	300	10
13.	Horsington Hill, two miles south of Harrow	278	(?)

Similar gravels are also described by Mr. Monckton and by the Survey Officers at Langdon Hills (378 ft.), and Rayleigh Hills (260 ft.), in S.E. Essex, and at Swanscombe Hill (400 ft.), in N. Kent, etc.

The constituents are as follows:

(*a*) Rounded flint pebbles up to 3 in. long. A very few larger were seen up to 9 in. These form the bulk of the gravel.

(*b*) Subangular and little worn flints.

(*c*) Red flint, generally in broken pieces; whole pebbles being scarce.

(*d*) Pieces of quartz of a dull white colour, not usually as well-rounded pebbles, but rough. These are by no means abundant, and, in some cases, almost entirely absent.

(*e*) Pink quartz is rarely found.

(*f*) A very few sandstone pebbles, dark chert, and lydian stone.

At Horsington Hill and Newgate Street chert is abundant and of good size, but is absent elsewhere.

At Stanmore Common and Tyler's Hill, Chesham, Hertfordshire puddingstone occurs.

The flint constituents are frequently ironstained, both internally

and externally, producing in the former case numerous examples of agate-like structure.

Many flints are weathered quite white, in some cases to the depth of half an inch.

The matrix is usually of a clayey nature, and of a deep brown ochreous colour.

In many places the upper pebbles for two or three feet were on end, presenting a curious appearance.

The heights of these deposits decrease from W. to E.; while at the same time the depth and bulk of the gravel increases. On Tyler's Hill, Chesham, there is a small patch 3 ft. deep, while at Warley there is an extensive patch 10 ft. deep. Those deposits also which lie farther S. and E., are of a rather simpler character, *e.g.*, at Warley scarcely a quartz pebble could be found.

B. Hampstead Type.

Localities:

1. Hampstead Heath; height, 450 ft.
2. Totteridge; height, 400 ft.
3. Coopersale Common, near Epping; height, 347 ft.

This is a very small and simple series, differing materially from the previous. Its constituents are:

(*a*) Flint pebbles from 2½ in. by 1½ in. downwards. The majority, however, are small, smooth, and often bleached.
(*b*) Subangular and little worn flints absent.
(*c*) Red flint present, but not abundant.
(*d*) Small quartz pebbles from 1 in. downwards to coarse sand. These form a considerable portion of the gravel [*cf.* A]. Besides pieces of dull white quartz, translucent and even transparent pieces are common.
(*e*) Pink quartz is prevalent [*cf.* A].
(*f*) Well-rounded and subangular pieces of chert or pinhole ragstone. These are generally referred to the Lower Greensand, and regarded as proof of the southern origin of the constituents of these beds. I am sceptical of this explanation of their nature and origin, but at present am not in a position to say more.

The majority of these constituents are very small. At Hampstead, after careful search, I found a few small red jasper pebbles, and a veined lydian stone.

The deposit at Coopersale Common, which is situated close to the railway line about midway between Epping and North Weald Stations, is covered by 14 feet of simple ochreous gravel, somewhat similar to that described in A.

At Finchampstead, on the right of the road leading from Wellington College Station, similar gravel is found in pockets

resting on the Southern Drift, and at Walton-on-the-Naze a very coarse quartz sand, with flint and quartz pebbles, is found underlying gravel similar to that described in the next series. The last is placed with the Chillesford Beds (?) by the Survey. I mention these as interesting facts, but I do not intend to draw any inference from them.

C. High Barnet Type.

This includes a series of gravels, usually with a sandy matrix of a more complex character and extending over a wider area than either of the preceding.

Localities examined:

1. Nettlebed, N.W. of Henley; height 665 ft.
2. Greenmore Hill, 600 ft.
3. Lane End near High Wycombe, 600 ft.
4. Penn (a small pit in Vicar's Garden, Tyler's Common), height 547 ft.
5. Coleshill, near Amersham, 500 ft. (560 ft. at highest point.)
6. South Mimms, 400 ft., in a wood N.E. of village.
7. High Barnet, 400 ft.
8. Potter's Bar, 359 ft. (old pits on the right of the main road).
9. Grigg's Wood, near Ayot, 406 ft.
10. Sacombe Park, four miles N.W. of Ware, 362 ft.
11. Collier's End, five miles N. of Ware.
12. (?) Dunmow Station 189 ft. (old pit).

The constituents of the above increase in complexity with the decrease in height eastward, beginning with very simple gravels, containing little besides flint and quartz, thus approaching B in character. Taken generally they contain:

(*a*) Flint pebbles, many of which are bluish or bleached.

(*b*) Subangular and little worn flints are present but not abundant. Tabular pieces, cylindrical forms, and green-coated flints occur frequently. Many flints are irregularly weathered. Iron-stained specimens are rare, except at Coles Hill.

(*c*) Red flints comparatively rare.

(*d*) White quartz, in various forms, is usually abundant.

(i.) Rough pieces, both of a dull white and a crystalline structure, from four inches by two inches to fragments.

(ii.) Rolled pieces of a similar character. Well-formed quartz pebbles are comparatively rare. In many places—*e.g.*, S. Mimms—much broken quartz is found.

(iii.) Quartz pebbles, with a peculiar reticulated structure, and usually of a darker colour. These are found very commonly in this and the next series, and appear to be ordinary quartz which has been subjected to some set of conditions which have produced innumerable flaws in its structure. Some, however, appear to be very clear quartzite.

(iv.) Translucent quartz.

(*e*) Pink quartz.

(*f*) Pinhole ragstone is present in places, *e.g.*, Coleshill, Barnet, and Dunmow, but is not generally abundant.

(*g*) Red Jasper, usually rare and small, but always present. [*cf.* Hampstead].

(*h*) Veined lydian stones, also rare but always present.

(*i*) Dark, glossy lydian stones, not veined.

(*j*) Dark chert (? Palæozoic).*

(*k*) Sandstone pebbles. A few but not abundant. [*cf.* A *f.*]

(*l*) Liver-coloured quartzites, a few very small pebbles.

(*m*) Light-coloured quartzites, a few.

(*n*) A very few rocks other than above.

The great paucity of specimens under the headings *k*, *l*, *m*, *n*, should be compared with similar headings in the next series. With regard to the light-coloured quartzites, I should like to state that I have found some with a brown or liver-coloured centre, and thus possibly some of the light ones may be derived from the red ones, the colour having in some way been dissolved out.

At South Mimms I found two pieces of what appears to be Carboniferous Chert with markings of Crinoid stems.

Near and at little difference of level at Coles Hill, Bucks, is a brickyard, in the clay of which blocks of Hertfordshire puddingstone are found.

If the trend of these deposits be compared with that of the A series it will be seen that lines drawn connecting them do not cross, although they come very close at Barnet.

The heights are rather less than those of the A series, and while these latter stretch far away into N. Kent and S. Essex, the former (C series) are found in Herts and N. Essex.

The whole of this series is included by Sir J. Prestwich in his "Westleton Beds."

D. **Bell Bar Type.**

This series differs from the preceding in occupying lower levels, in the coarseness, greater size, and complexity of its

* Dr. G. J. Hinde, F.R.S., has examined these, and finds that many of them contain casts of Radiolaria, which are similar in character to those found in Carboniferous rocks, *e.g.*, Culm Measures of Devon.

constituents, and in their close proximity, both in a vertical and horizontal direction, with beds of a distinctly glacial type.

Localities:

(1) Bowsey and Ashley Hills, 467 ft.—480 ft.
(2) Bell Bar, 360 ft.
(3) Bayford, near a large pond and blacksmith's shop, 300 ft.
(4) Hertford Heath, 2 miles S.E. of Hertford, 300 ft.
(5) Epping Forest, 370 ft.
(6) Great Easton, nr. Thaxted, Essex, 250 ft.

Constituents:

(*a*, *b*, *c*) Flint similar to that described in C. Red flint and bleached pebbles are rarer, smaller, and unbroken.
(*d*, *e*) Quartz similar to that in C, but larger, *e.g.*, 10 in. long at Bell Bar, and very plentiful.
(*f*) Pinhole ragstone far more abundant than in C.
(*g*) Jasper more abundant and of a larger size.
(*h*, *i*) Lydian stones, ditto.
(*j*) Dark chert.*
(*k*) Sandstones and Sarsens both large, various, and plentiful

At Epping Forest I saw three, measuring 9 in. by 5 in., 12 in. by 6 in., and 20 in. by 5 in. respectively.

(*l*) Liver coloured quartzites, larger and more plentiful.
(*m*) Light coloured quartzites, some being red and glassy.
(*n*) Other rocks various and plentiful. Among them may be mentioned:
(i.) Conglomerate blocks up to 9 in. long at Bell Bar.
(ii.) Argillaceous sandstones (?).
(iii.) Grits.
(iv.) Various.

The Epping Forest gravels differ slightly from the rest in having a much greater proportion of flints and fewer quartz pebbles. They appear to be a mixture of gravel of this series, and that of the A series.

As in the case of the series A and C, the heights decrease from west to east. These are included by Sir J. Prestwich also in the Westleton Series.

E. High Level Glacial Gravels.

While examining various districts in search of the series of gravels just described (A to D), I was struck on many occasions by the close proximity to them of beds of gravel containing large numbers of liver-coloured quartzites and other derived rocks. Many of

* See footnote on p. 393.

these are recognised as occurring *in situ* in the N. and N.W. of England, and consequently they are stated to occupy their present position as a result of that great removal of material which took place during or at the close of what is generally termed the Glacial Period. These gravels approximate in composition most closely to those of the D type, but their constituents are more coarse and complex, and they occupy, in similar localities, slightly lower levels. Many of them, however, are over 300 ft. above O.D

1. Upper Basildon, on the S. side of Goring Gap, is 466 ft. high. This and numerous other similar deposits described by Mr. Osborne White are quite close to the patches of Pebbly Gravel found between 480 — 650 ft. in that neighbourhood, *e.g.*, Bowsey Hill, Nettlebed, Greenmore Hill, and many others.

2. St. Albans (near churchyard), 325 ft. Sir Joseph Prestwich described Pebbly Gravel on Barnard Heath, 406 ft., which is quite close.

3. Harefield, 200 ft., over the Chalk, is near Coleshill.

4. Whetstone, Finchley, and Oakleigh Park, which are over 300 ft. O.D., and close to Hampstead, Totteridge, Barnet, etc.

5. Stondon Massey, E. of Ongar, 200 ft. Here the top of the hill on which the church stands is capped with a white quartz gravel, similar to that described under D, while lower down the slopes ochreous Glacial Gravel, of a totally different composition (*cf.* Bramford, p. 397), is abundant.

6. Witherspoons, four miles E. of Ongar, over 300 ft. high, is quite close to Norton Heath, described under A. Here liver-coloured quartzites, large sarsens (2 ft. by 1½ ft.), conglomerate, rough quartz blocks (1 ft. by 1 ft.), rolled chalk, 8 in. by 7 in., abound. It is about 7 ft. thick.

7. Ayot, nearly 400 ft., near station (G.N.R.). Grigg's Wood, mentioned under C, is quite close.

8. Welwyn, 250 ft., has pits with *Gryphæa*.

9. Codicote, 356 ft., and Woolmer Green, 315 ft., farther north of 7 and 8, have large gravel sections which yield abundant red quartzites, etc.

10. Pepper Hill, 200 ft. about, near Hertford, is close to the deposits at Bayford and Hertford Heath, mentioned under D.

11. In the Thaxted Valley coarse Glacial Gravel with abundant *Gryphæa* is found at a slightly lower elevation than the gravel at Great Easton described under D.

12. Dartford Heath gravel with *Gryphæa* is near Shooters' Hill.

It will thus be seen that in those districts where Pebbly Gravel is present, beds of acknowledged Glacial origin are in close proximity.

I shall follow this point further in a later part of this paper.

III.—EAST ANGLIAN DEPOSITS.

Up to the present I have treated only of deposits lying between Goring Gap and the western and southern portions of Essex. This has been done in detail in order to obtain a definite grasp of the various varieties of pebbles, etc., found. It is now my intention to trace them farther N.E. In doing so a tract of country is brought under consideration containing beds of gravel about which much dispute has arisen, and I think I cannot do better at the present stage of this paper than to very briefly place before you some of the disputed points, and then state in detail my own experiences and opinions with regard to them. By means of various deposits near Thaxted, Bures, Sudbury, Stoke, Ipswich, etc., Sir J. Prestwich endeavours to connect the gravels described under C and D with a vast spread of gravel on Westleton Heath (near Dunwich) and Southwold, and then correlates these latter with various deposits on the Norfolk coast. He regards most of them as of marine origin, chiefly in consequence of the discovery of shells and casts of shells at, and close to, Southwold; and accounts for the absence of shells, etc., at Westleton and places farther inland, by decalcification. The gradual rise of the Pebbly Gravel westward is accounted for by a rise in the land, which left the beach of the Westleton Sea high and dry to be attacked by denuding agents, which have left us the few patches previously described.

Mr. Whitaker and other officers of the Survey, in various Memoirs relating to this district, regard the sands with pebbles in N. E. Essex and E. Suffolk, described by Sir J. Prestwich, as Crag (?), and refer the gravels at Westleton, Southwold, etc., to an indefinite Pebbly Series.

On the Norfolk Coast the beds claimed as Westleton are placed by Mr. C. Reid in the Weybourne Crag (part), *Leda myalis* Bed, or Arctic Freshwater Bed.

Mr. S. V. Wood, junr., considered both the Pebbly Series of Suffolk and the gravels in the Bure Valley as belonging to his Lower Glacial series, while Mr. H. B. Woodward regards these Bure Valley Beds as part of the Norwich Crag series, and is, I believe, of opinion that the Pebbly series in Suffolk is of Glacial origin.

1. N. E. Essex and S. Suffolk.

In his Westleton paper Sir. J. Prestwich describes numerous sections on the G.E.R. which are now totally hidden, together with others near Thaxted, Stoke, Sudbury, Bramford, Elmsett, etc., now accessible, and which I shall proceed to briefly describe :

1. Between two and three miles south of Thaxted, and quite close to the gravel pit near Great Easton described under D, is a section of ferruginous sand containing shell fragments, false-bedded, and similar to deposits to be described later on at Sudbury. It was totally unlike anything described in Part I. The Survey mark this as Crag (?), which is most probably correct.

2. At Burnt House, near Stoke, similar sands with included flint pebbles occur over the Chalk, and are overlain by Glacial deposits. Shells of a similar character to those found at Sudbury have been found at the base of these sands.

3. Around Sudbury there are numerous exposures. Sandy beds again occur below Glacial clay and gravel, and in one pit a distinct band of pebbles 1 ft. thick was found. The sands contain numerous Crag shells, and I picked up two worn phosphatised sharks' teeth from a heap of the sand. The gravel mentioned is full of phosphatic nodules together with flint and a little quartz.

4. At Bramford, 3 miles from Ipswich, similar sandy beds occur beneath Glacial clay and gravel. The gravel at the back and highest part of the pit bears a very strong resemblance to the D type, and in these pits we appear to have a similar feature to that described at Stondon Massey under section E. Quartz gravel caps the sand at the top of the hill, and Glacial clay surrounds the lower portions.

5. The pit at Elmsett is now an orchard, but two or three large hard blocks of quartz conglomerate were still to be seen.

To sum up, I may say that in this district I saw nothing comparable with any of the deposits described under A—D, but only sandy beds containing Crag fossils. The gap which thus occurs in the Pebbly Gravel deposits in this part of East Anglia will be explained in a later part of this paper.

Beside the Glacial beds mentioned above, both in the Thaxted and Sudbury valleys there was plenty of further evidence of such, *e.g.*, Glemsford Station and Cavendish, where abundance of *Gryphæa* is found.

2. Eastern Suffolk and Essex Naze.

In this, the typical district, Pebbly Gravel is well developed, and can be studied both in the cliffs and in inland sections. All the gravel is below 100 ft. O.D., and is in places 30 ft. thick.

Southwold Cliff is overgrown, but those at Covehithe and Easton Bavent to the north are well exposed. In these the gravel is of a simple ochreous type, mainly composed of flint pebbles in a sandy matrix. Small quartz pebbles are fairly abundant.

At Southwold, the Chillesford Clay which underlies the gravels farther north is absent, and, consequently, at this point they lie

directly on the Crag, and it is important to note that it is here that the marine shells and casts referred to were obtained,

Inland at Blythburgh, Reydon, and Halesworth, sections of similar gravel are to be seen.

Dunwich Cliff to the south of Southwold contains much Pebbly Gravel resting on sands and forming in places channels 30 ft. deep.

The most cursory glance at the constituent pebbles here shows that this gravel markedly differs from that just described. It has a bluish tint, and contains, besides flint pebbles, much small quartz and several kinds of foreign pebbles.

A small pit on the edge of the cliff gave a similar section 10 ft. deep, and the gravel could be easily traced across Dunwich Heath to Westleton, where on the south side of the village a large new section is to be seen. It is 17 ft. deep, and is 83 ft. O.D.

The gravel here is very white, not, however, from an abundance of quartz, but owing to a large number of the flints being bleached quite white. Ninety-nine per cent. at least of the material is flint, chiefly pebbles, the other one per cent. being made up of quartz pebbles and other rocks similar in character to those described in the C or High Barnet series of Part I. They are identical with those in Dunwich Cliff. Several of the flints break into a number of pieces easily and some show concentric and other iron markings. Interbedded with the gravel are thin, oblique bands of sand similar to that which forms the matrix. Dunwich Cliff shows similar sandy patches. The largest flint measured 7 in. by 4 in.

Overlying the Red Crag at the Essex Naze very similar gravel, with a layer of coarse sand at the base, is found

It is therefore seen that in this district we have *two distinct kinds of gravel*: that at Westleton, etc., similar to the C type, and that at Southwold, etc., similar to the A type. From the latter marine shells belonging to Crag species have been found, and are regarded by many geologists as drifted. In the former no shells have ever been found.

As far, then, as the typical district at Westleton is concerned, there is no evidence of a marine origin for these gravels.

To the north of Easton Bavent Cliff, between Kessingland and Pakefield, Boulder Clay and other Glacial deposits are found in the cliffs, and derived fossils are easily procured from them, thus showing again the close proximity of undoubted Glacial Deposits to the Pebbly Gravel.

3. Norfolk.

As Sir J. Prestwich includes some of the beds exposed on the Norfolk coast in his Westleton Series, I visited this district and studied the cliffs from Weybourne to Cromer, and from Triming-

ham to Bacton, paying particular attention to those sections mentioned by him.

At the two extremities of the great Glacial accumulations on that coast—Weybourne and Bacton—a gravel occurs underlying, and differing widely in composition from, the undoubted Glacial Gravels above them.

At Bacton they fill up what is apparently a wide channel in the underlying beds, and are referred, I believe, by Mr. C. Reid, to a river bed. In his Cromer Memoir he gives a detailed account of the composition of this gravel, which is of great importance. He, further, traces deposits of a similar character as far inland as Woodton and Withersdale in the Yare Valley. At the former place a block of Hertfordshire puddingstone was found.

The gravels at Weybourne are referred by him to the Forest Bed series (?) also.

At Thorpe Hamlet, near Norwich, 100 ft. O.D., on the slope of the rising ground near Pull's Ferry, a gravel similar to the above, 20 ft. deep, is found below 20 ft. of ochreous Glacial Gravel.

The composition and general character of each of the above are singularly like the D type of gravel described in Part I, especially that occurring at Bell Bar and Bayford.

At no other places did I see any gravel at all comparable with that in our district north of the Thames.

The Bure Valley Gravel Beds as they occur at Colteshall, Whitlingham, and Bramerton are composed almost entirely of flint. They are very ochreous, and in places stained black by oxide of manganese. They approach in character the gravel of Easton Bavent Cliff, etc., but I doubt if these two had a similar origin as stated by Mr. S. V. Wood.

Both *in situ* and on the strand red jasper pebbles and veined lydian stones were frequently observed.

IV.—CONCLUSIONS.

Before proceeding to generalise respecting the complicated and widespread series of deposits just described, it is fitting to pause here and consider the theory which attempts to explain the origin of a portion (C and D) of these gravels by regarding them as a beach, which since its formation has been gradually lifted in a N.W. direction.

At first sight the perfectly-rounded flint and other pebbles would naturally lead us to such a conclusion; but these flint pebbles are, there is little doubt, the *débris* of previous Tertiary pebble Beds, and the quartz pebbles are by no means all rounded, such as would be the case if the Westleton beach were at all comparable with such a beach as the Chesil Bank, in Dorset.

The palæontological evidence, which was supposed to support this view, has been shown previously to be inapplicable to these beds.

Denuding agencies are credited with a great deal of removal, judging by the long gaps between these small, scanty deposits; but if such were the case, much larger accumulations of this kind of gravel would be found at lower levels, mixed with other kinds. My experience leads me to believe that such is not the case.

Again, there are many positions along the flanks of the Chilterns and other places further N.E. devoid of gravel, which have apparently been less affected by denuding agencies than those in which they are found.

The gradual uplift to the N.W. is not borne out when rigidly applied to particular districts; and, if a rising has taken place, the lower solid beds would have been disturbed, and faults probably formed. I am not aware that this is the case in a single instance. Nettlebed, 665 ft., is but eight miles from Bowsey, 480 ft.; and South Mimms, 400 ft., is but seven miles from Bayford, 300 ft.; while Barnet, 400 ft., is about eighty miles from Westleton, 83 ft.

It has been suggested that the lower members are re-assorted or disturbed higher ones, but I see no good reason for such a view.

The total absence of fossils, although explained by decalcification (of which, however, no signs whatever appear), also militates against the theory that these are remnants of a beach.

I will now draw your attention to the following points respecting *all* the gravels.

1. Beds of undoubted Glacial origin occur in close proximity to all.

2. The gravels nearly all increase in complexity with decrease in height, the South Essex and Kent gravels alone excepted.

3. Each series separately decreases in height towards the east, as before pointed out.

4. The bulk and surface extent increase in the same direction.

5. The variety of rocks foreign to the district, the quartz fragments being of several kinds.

6. The similarity of materials over such a wide area.

7. The presence at varying heights of these deposits in the vicinity of those gaps in the high ground running from Goring in a N.E. direction into Norfolk, and their absence elsewhere.

8. The increase in the complexity of the gravel material with the decrease in height of the gaps.

These last two points are so important that I will describe the gaps in greater detail.

(*a.*) Goring Gap.

This gap, through which the Thames now flows, is about 160 ft. O.D. at its lowest point. The gravels around this gap have been minutely described by Mr. Osborne White in a paper read before this Association. Three distinct types of High Level Gravel are met with, viz.:

1. A simple series, consisting mainly of flint and quartz pebbles in a sandy matrix, at Nettlebed, Checkendon, Greenmore Hill, etc., situated at heights about or above 600 ft. O.D., and belonging to series C of Part I.

2. A more complex series at rather lower levels, containing a greater variety of stones, *e.g.*, Bowsey and Ashley Hills, 450-480 ft. (D series).

3. Gravel which, from its containing pebbles of red quartzite in abundance, may be called Glacial, *e.g.*, Upper Basildon, 426 ft. O.D. (E series).

Glacial Gravels also occur lower, and these are succeeded by the terrace gravels of the Thames valley.

(*b.*) High Wycombe Gap.

The lowest part here is much higher than the previous one. At Lane End, 600 ft., judging from the specimens kindly obtained by Mr. Upfield Green, and at Tyler's Common, Penn, 580 ft., the gravel belongs to series C.

Quite close to the latter is a different gravel of a simple ochreous type. It is quite possible that if this gap and its vicinity are examined carefully other sections may be found.

As far as I know, Glacial beds are absent, and this is explained by the height of the water-parting above O.D.

(*c.*) Wendover Gap.

The height of the water parting is here over 400 ft. Gravel of the A type is found at Cowcroft or Tyler's Hill, Chesham, while at Cole's Hill, near Amersham, the C type is found, being of a more complex composition than that of Nettlebed, Penn, etc., further west.

At Hyde Heath, 570 ft., near Great Missenden, visited by the Association,* is a deposit of large flints and boulders of conglomerate, while during the cutting of the Metropolitan Railway extension to Aylesbury, sections of gravel were to be seen having a decided drift appearance.

Over the Chalk, at Harefield, 200 ft. O.D., is a Glacial Gravel, probably connected with this or one of the following gaps.

* *Proc. Geol. Assoc.*, vol. xii (1892), p. 340.

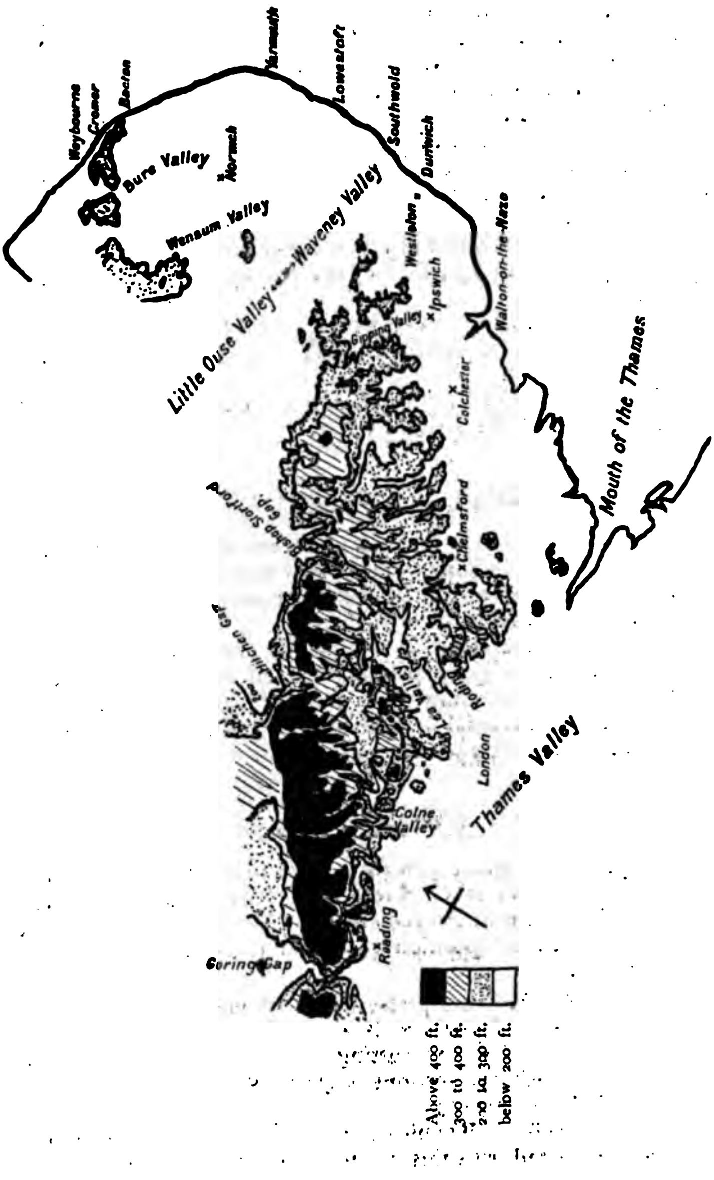


FIG. 1.—CONTOURED MAP OF THE COUNTRY BETWEEN GORING AND THE NORFOLK COAST.
Scale: 24 miles to the inch.

(*d*, *e*.) Hitchin and Bishop Stortford Gaps.

The water parting is 305 ft. O.D. and 298 ft. O.D. in these ps respectively.

From the contour map it can easily be seen that these two converge, the first being in a N.W. to S.E., and the second a N. to S. direction. As a consequence, the deposits to the south of them are more numerous and complete than the preceding. The heights, too, are lower. The following list shows the groups connected with these gaps:

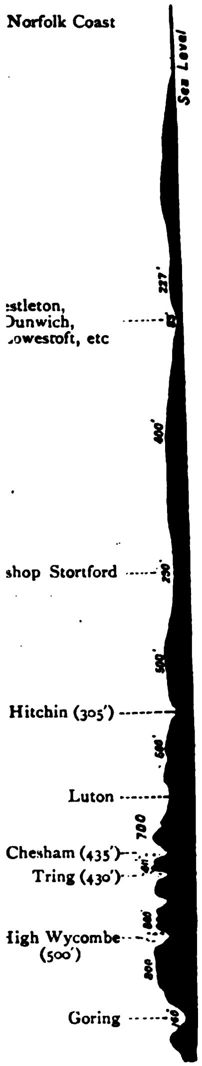


FIG. 2.—SECTION ALONG THE HIGHEST GROUND BETWEEN GORING AND THE NORFOLK COAST, SHOWING THE POSITIONS AND HEIGHTS OF THE VARIOUS GAPS.

A. Barnet Gate, Stanmore Common, etc.
B. Hampstead Heath, Totteridge, Coopersale Common.
C. High Barnet, South Mimms, Grigg's Wood, Sacombe, Collier's End, etc.
D. Bell Bar, Bayford, Hertford Heath, Epping Forest.
E. (Glacial) Whetstone, Finchley, Broxbourne, Pepper Hill, St. Albans, etc.

The Thaxted Valley is an offshoot of (*e*), and in it is found gravel of the C, D, and E types.

(*f*.) Westleton Gap.

Beyond this there are no decided gaps for some distance, and this explains why there is an apparent absence of these gravels in N.E. Essex. The valleys of the Waveney and Little Ouse form a broad low gap. They rise close together at about 86 ft. O.D., and flow in opposite directions. Around the broad mouth of this gap a similar series is found.

A. Ochreous Group, Halesworth, Easton Bavent. Covehithe, Southwold, etc.
C. Westleton, Dunwich, Essex Naze.
E. Glacial, Lowestoft to Kessingland.

Gravel of the D type was not seen in this district but at Bacton Cliff, Norwich, and Weybourne (?) all of which have open communication with this gap.

Taking all things into consideration I cannot help coming to the conclusion that in these Pebbly Gravels we have, not the fragmental remains of a beach, but rather the first instalments of transported material usually ascribed to Glacial or Ice agency. The presence of liver-coloured quartzites is usually taken as a test of glacial origin, but it is quite possible that the beds from which these come were not attacked at the very outset of the break-up of Glacial conditions. This is extremely probable, as we find a few of them in the C series, more in D, and large numbers in E.

The gradual decrease in height from N.W. to S.E. would point to direction of warmer conditions, and the varying heights of the deposits round the gaps may point to stages in the break-up.

The increase of complexity with decrease in height is quite in accordance with a drift origin, as lower beds would become subject to the action of the removing force, and thus afford a greater variety of material.

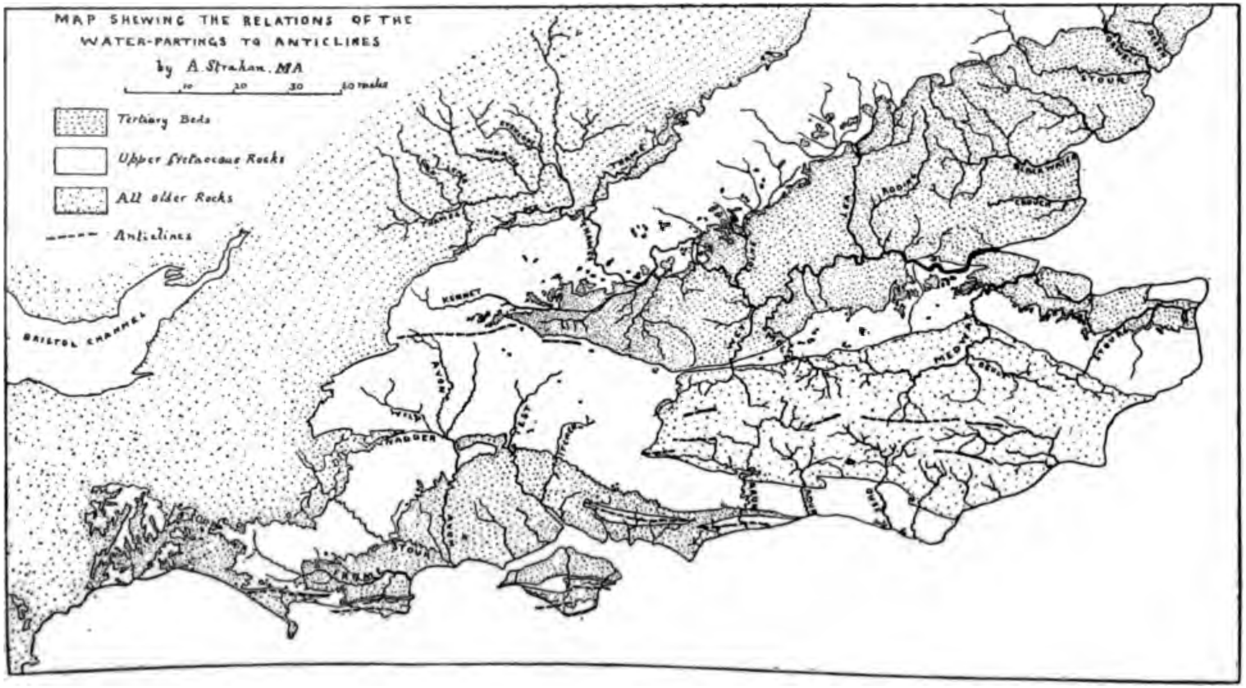
The gravels of the A series do not group themselves round the gaps to such an extent as the others. This is easily accounted for, since, being the earliest, their materials were derived from the immediate vicinity, and possibly in great part from the southern side of the gaps. The large number of Tertiary outliers to the north point indirectly to this conclusion.

If the warmer regions lay to the S.E., it is quite in keeping to find the thickest deposits in that direction also.

The similarity of materials over such a wide area points to a distant focus of origin rather than lateral communication.

The quartz pebbles are of several varieties, and had possibly as many sources of origin.

If what I have inferred from my observations is correct, and I have every confidence in my deductions, then the term Westleton Series will not apply to these as a whole, neither does High Level Drift, nor Pebbly Series necessarily, and I beg to suggest Early Drift, or some such name, for these, the first deposits of the Glacial Series.


MAP SHEWING THE RELATIONS OF THE
WATER-PARTINGS TO ANTICLINES
by A. Strahan, MA
10 20 30 50 miles
Tertiary Beds
Upper Cretaceous Rocks
All older Rocks
Anticlines
BRISTOL CHANNEL
THAMES
KENNET
AVON
WYLY
NADDER
TEST
STOUR
FROME
MEDWAY
BLACKWATER
CROUCH
RODING
LEA
STOUR

ON THE PHYSICAL GEOLOGY OF PURBECK.

By A. STRAHAN, M.A., F.G.S.

(With Plate XIII.)

[*Read 1st May*, 1896.]

IN dealing with the origin of the physical features of the Isle of Purbeck, it is necessary to consider those of the south-east of England generally. For the purpose of so doing I have prepared a map (Plate XIII) showing the river courses in detail, and have placed on it the limits of the Tertiary deposits and of the Upper Cretaceous Rocks, the last-named being selected as forming one of the most important stratigraphical horizons in our Secondary Rocks. The crests of the principal anticlines also are indicated.

These Upper Cretaceous Rocks extend across England in a general north-easterly direction, and with a general south-easterly dip; but their structure is diversified by some important folds, which run nearly east and west. Of these the more important are the London basin, the Wealden anticline, the Hampshire basin, and the Isle of Wight and Purbeck anticline.

The rivers may be considered as consisting of two main lines of drainage running from west to east along the synclines, and of a number of tributaries which flow north and south from the anticlines. Thus the Thames and Kennet pretty closely follow the axis of the London syncline from end to end. On the north there are gathered into this main stream a number of tributaries rising on the back of the Chalk escarpment, amongst which may be included the stream known to geographers, from its superior size, as the Thames, but which for present purposes might be regarded rather as a tributary of the Kennet. This stream, it may be noted, with its contributaries—the Coln, Leach, Windrush, Evenlode, and Thame—rises in the Oolite tract, some distance beyond the Chalk scarp.

On its south side the Thames receives a number of tributaries which rise in the low ground of the Weald, and traverse the bold Chalk range of the North Downs. The reason for this apparently anomalous course has become a classic problem in geology. The Wealden area, for the most part lying low and overlooked on three sides by bold Chalk hill-ranges, was once supposed to have originated as a bay of the sea. It has been shown, however, that its form resulted solely from atmospheric denudation. Originally an elevated area with the structure of an arch it gave birth to a number of streams flowing north and south from the axis of greatest altitude, which then coincided with the axis of greatest upheaval; and though subsequently the crown of the arch was denuded away, and the high area reduced

to a valley, the rivers kept their courses and deepened them simultaneously with the general degradation of the land. As a test of this theory, it may be seen by the map that the main anticlinal axis of the Weald agrees closely with the water parting between the rivers which flow north and south respectively from that area. The agreement is even more striking further west, near Kingsclere, where a valley breaches the Chalk escarpment, but plays no part in carrying the drainage of the district, the streams in fact flowing from it and not to it. Here again the geological structure furnishes the explanation, for the valley coincides with the well-known Kingsclere anticline, by which the position of the water-parting was determined.

The Frome and its tributaries form a system precisely analogous to that of the Thames and Kennet, though a larger portion of it has been removed by the sea. The main line of drainage, as in the case of the Thames, follows the synclinal axis, and though it now enters the sea at Poole, its former course is recognisable in the valley occupied by the Solent. From the north it receives the Stour (which rises in the Oolitic area and thus forms a curiously close counterpart of the Upper Thames), the Avon, which comes down from the Kingsclere anticline, and the various Southampton rivers, while finally the Arun, Adur and Ouse must at some former period have formed tributaries to this main stream. On its south side, there remains a mere wreck of the former drainage area, but enough to give an idea of its configuration. The Isle of Wight, as has been frequently noticed, is divided into three parts by two alluvial tracts, the one running from Freshwater Gate to Yarmouth, the other from Sandown to Bembridge. The former is bordered near Freshwater by terraces of river-gravel, and though it leads out into the sea at Freshwater Gate, its continuation, with corresponding terraces, strikes the land again near Brook, and runs thence for some distance at or near the brow of the cliff. We have here, in fact, a river-valley, with alluvium and terraces complete, but tenanted by no stream, the encroachment of the sea having tapped the waters at their sources. The same description applies to the Sandown alluvial flat; this marsh indicates the former course of a stream, the whole drainage area of which has been swept away, with the possible exception of the ground drained by Shanklin Chine. The Medina, on the other hand, in the middle of the island remains intact. This and the vanished streams above described followed the invariable rule, and, rising in the crest of the Isle of Wight anticline, made their way, regardless of the apparent obstacle formed by the Chalk range, to the main stream in the syncline.

The Isle of Purbeck provides a no less conspicuous example of the same law. It is traversed in its southern part by a continuation of the Brixton anticline of the Isle of Wight, the crest

of the anticline however, as so often happens, coinciding with what is now low ground, while the principal hill-range is formed by the Chalk outcrop farther north. The streams, as elsewhere, rise on the anticline and flow northwards from it straight at and through the Chalk range, taking so little account of it, so to speak, as to have cut two deep gaps through it in close proximity, leaving the conical hill of Corfe Castle between.

Still further south we find small portions of a third drainage system, for the southern water-parting of the Frome basin touches the southern parts of both the Isle of Wight and of Purbeck, and even turns inland west of Purbeck. The small combes south of this parting are the heads of valleys which led down to another drainage system now entirely swept away.

Thus the Isle of Wight became an island through the combined action of the sea and the Frome. The sea, encroaching upon the old estuary of the river, effected the separation on the north, while a tributary to the Frome, we may suppose, had commenced a breach in the Chalk range somewhere between the Needles and Ballard Point. A submergence such as that of which we have evidence in the submerged peats of Southampton Docks, would admit the sea to that breach, and the tide, once given a clear run round the island, would make short work of sweeping out the old alluvia and widening the channels to their present dimensions. The Isle of Purbeck marks an intermediate stage in such an insulation; the tidal estuary on its north side already exists, and a submergence sufficient to admit the sea to the Frome valley round the west end of the Isle of Purbeck Chalk range would bring into existence a second Isle of Wight. The history of the insulation seems to resemble strongly that of Barry on the coast of Glamorganshire.*

All the anticlines I have mentioned have the same general form, namely a steep upward bend of the strata on their north sides, and a gentle descent towards the south. The movements, however, have been more energetic in the extreme south of England than in the central Counties; and while the folding is more complete in the Isle of Wight than in the Weald, it has gone still a stage further in Purbeck and at Ridgeway. The strata, in fact, having there bent as far as they could go, the further strain was relieved by fracturing and overthrusting of a unique character, as I have elsewhere described.† I then assigned these disturbances to two ages, viz.: the intra-Cretaceous folds, which affect all rocks up to and including the Wealden, and the post-Cretaceous folds. Since then Mr. Reid has shown that these later folds themselves belong to more than one age.‡ We may further assume, from the vast discordance between the Trias and Carboniferous in

* *Quart. Journ. Geol. Soc.*, vol. lii (1896), p. 474.
† *Quart. Journ. Geol. Soc.*, vol. li (1895), p. 459.
‡ *Quart. Journ. Geol. Soc.*, vol. lii (1896), p. 490.

South Wales, that there were movements still earlier than the intra-Cretaceous. But at whatever age they recurred, they all seem to have caused folding in a general east and west direction, and their repetition along nearly the same lines, epoch after epoch, must have left the Palæozoic rocks which underlie Dorset in inconceivable confusion.

In the Lower Purbeck rocks a curious rock-structure occurs, the age and origin of which still forms a subject of discussion. The limestones immediately overlying the Dirt-bed assume at times the character of a breccia. They have been broken into angular blocks, which are quite disarranged and now stand at all angles, the whole, however, having been recemented into a coherent rock. This brecciation affects as much as 40 ft. of strata at times, yet the beds beneath and above the broken belt are undisturbed. By Sedgwick and Murchison* the structure was compared to that which occurs in certain Devonian limestones; these rocks are interstratified with shales, and having been subjected to pressure have broken while the shales yielded. Mr. Fisher,† on the other hand, pointed out that the strata above the "broken bands" were not only undisturbed, but that they tended to level up the inequalities due to the breaking, a fact which left him in no doubt that the brecciation took place before the upper strata were deposited. But Mr. H. B. Woodward ‡ has lately argued that the structure is connected with the Isle of Purbeck disturbance, and must therefore be post-Purbeck, and probably even post-Cretaceous, but Mr. Fisher's arguments would have to be met before this conclusion could be accepted. Mr. Fisher further suggests that the breaking up was due to the falling in of the tufas consequent on the decay of the mass of vegetation which they had enclosed. It may be noticed also that a brecciated character is not an uncommon accompaniment of tufas of all ages.

In conclusion it may be pointed out that the features of the Dorset and Hampshire coasts are due to the encroachment of the sea on the old drainage area of the Frome, and to the almost complete obliteration of another water-system south of it. It is tempting to speculate on the part once played by this obliterated system, and by others beyond it, but perhaps similar to those I have described, in the formation of the English Channel and consequent separation of England from the Continent. We may call to mind the suggestion that before these changes, and probably at no distant geological period, these various streams formed tributaries of a far more important river which flowed northwards up what is now the North Sea, and of which the Rhine is the diminished representative.

* *Trans. Geol. Soc.*, Ser. 2, vol. v, p. 655.
† *Trans. Camb. Phil Soc.* vol. ix (1855), p. 566.
‡ *Jurassic Rocks of Great Britain* (*Mem. Geol. Survey*), vol. v (1895), pp. 247-251.

EXCURSION TO THE TATTINGSTONE CRAG DISTRICT OF SUFFOLK.

SATURDAY, 6TH JUNE, 1896.

Directors: THE PRESIDENT AND E. P. RIDLEY, F.G.S.

Excursion Secretary: A. C. YOUNG.

(*Report by* THE DIRECTORS.)

ARRIVING at Bentley Station the party was joined by members of the Ipswich Scientific Society, and collected first from two Red Crag sections close to the station, both of which had been specially opened for the occasion. Leaving these, a walk of about a mile brought the party to other Red Crag pits, near Tattingstone "White Horse." In all these sections specimens were very abundant, but generally much broken. The following were amongst the finds of the various members of the party:

Capulus
Cerithium
Cypræa Europæa
Emarginula
Nassa reticosa
Natica
Pleurotoma
Purpura lapillus
,, *tetragona*
Trochus subexcavatus
Trophon antiquus
,, ,, var. *contrarius*
Turritella incrassata
Voluta Lamberti

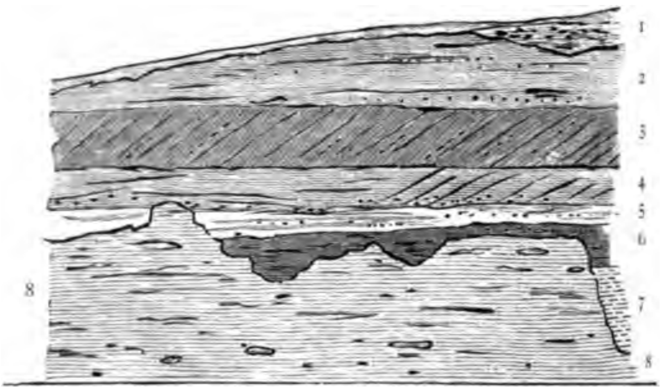
Artemis lincta
Astarte Basteroti
,, *sulcata*
Cardita senilis
Cardium sp.
Cyprina Islandica
Diplodonta astartea
Mactra sp.
Modiola
Mya arenaria
Ostrea
Pecten maximus
,, *opercularis*
Pholas
Tellina
Venus casina

Crab claws
Balanophyllia caliculus
Sphenotrochus

A move was then made to Tattingstone Hall, and after lunch the junction of the Red Crag and the Coralline Crag was examined at an opening in the farm yard. The section here formerly exhibited the unconformity between the two formations, as is shown in the figure (p. 410), and has been described by Lyell and Prestwich.

The Coralline Crag (Bed 8 in the figure) has been so greatly eroded that only a reef has been left, and the Red Crag (Beds 2 to 7) rests on the eroded surface and is banked against a cliff of the older rock. The section figured above is now obscured, but the Coralline Crag and the junction are still well exposed and were carefully examined. Here the "White Crag" consists almost entirely of fine comminuted white shells mixed up with

small pieces of polyzoa. Mr. Kennard found a *Solen* in its natural position boring into the upper part of the Coralline Crag. In the shelly part of the Red Crag *Pectunculus* was abundant, and from the base of this bed, just above the Coralline Crag, Mr. Atkinson dug out a cetacean vertebra ($6\frac{1}{2}$ ins. long by $5\frac{3}{4}$ wide) probably belonging to one of the ziphioid whales known as *Mesoplodon*. This specimen was very generously made over to the Museum of Practical Geology by the discoverer. A walk of about two miles brought the party back to Bentley Station.



SECTION AT PARK FARM, TATTINGSTONE, NEAR IPSWICH.—*Sir Joseph Prestwich.*

Coarse Gravel.	1.
Red Crag, 12 feet.	2. Ochreous sands with seams of ironstone, etc.
	3. Crag with a few coprolites.
	4. Light-coloured Crag.
	5. White sand.
	6. Brown loam.
	7. Face of old cliff, depth not shown.
Coralline Crag, 8 feet.	8.

(Reproduced by permission from *The Quarterly Journal of the Geological Society.*)

The district is generally a good collecting ground for Red Crag fossils, and is the farthest known southern exposure of the Coralline Crag.

REFERENCES.

Geological Survey Map, Sheets 48, N.W., 48 N.E.
Geological Survey Index Map, Sheet 12, colour-printed. Price 2s. 6d.

1871. PRESTWICH, SIR JOSEPH.—"Crag Beds of Suffolk and Norfolk." Part ii. *Quart. Journ. Geol. Soc.*, vol. xxvii, p. 325.

1885. WHITAKER, W.—"The Geology of the Country round Ipswich, etc." *Mem. Geol. Surv.* Price 2s.

1890. REID, C.—"Pliocene Deposits of Britain." *Mem. Geol. Surv.* Price 5s. 6d.

See "Record of Excursions," p. 187, *et seq.*, for report of former excursions to Suffolk.

EXCURSION TO READING.

SATURDAY, 13TH JUNE, 1896.

Directors: J. H. BLAKE, F.G.S., AND H. W. MONCKTON, F.G.S.

Excursion Secretary: H. A. ALLEN, F.G.S.

(*Report by* THE DIRECTORS.)

THE members assembled at Paddington Station, and travelled by the 1.33 p.m. to Reading, where they were met by Mr. J. H. Blake, and proceeded at once to the Reading Museum.

The fines collections of Roman remains from Silchester, and of flint implements discovered in the neighbourhood of Reading, were duly inspected, and a pot containing numerous Roman coins, recently found in the gravel on Bob's Mount, attracted attention. Much regret was expressed that the honorary curator, Dr. Joseph Stevens, was unable to be present through ill-health.

Leaving the Museum, the party walked to the Katesgrove Brickfield, which is worked by Messrs. Poulton, who had kindly given the Association leave to visit the sections.

The brickfield is situated on the east bank of the River Kennet, and the section was described by Professor Buckland as long ago as 1816. The part described was, however, somewhat to the north of the present workings. Katesgrove was first visited by the Association in 1876, and the account of the excursion, by Mr. Hudleston, will be found in the "Record of Excursions," page 269. It was again visited in 1885 and 1888, in each case during a whole-day excursion, and the present was consequently the first half-day excursion to the locality.

The section seen on the present occasion consisted of Reading Beds overlain by the Basement-bed of the London Clay and the latter by Plateau Gravel.

The upper part of the Reading Beds was composed of from 40 to 50 feet of mottled crimson, grey, and brown plastic clays, from which fossils have not been recorded; beneath, were stratified and false-bedded buff-coloured sands, in which a few lenticular masses or beds of more or less laminated grey clay occur, containing leaves of plants, and which are known as the "Leaf-beds." Specimens of the willow and other trees were obtained by some of the members, but the bed here being somewhat sandy the leaves were not so well preserved as in the adjoining Waterloo brickyard, where the beds are more clayey. The "Bottom-bed," showing the junction with the Chalk, which had recently been dug down to at this spot—the south-western part of the excavation—was unfortunately hidden by rain-wash.

NOVEMBER, 1896.]

For many years excellent sections showing the junction of the Reading Beds and the Chalk were exposed on the opposite side of the River Kennet at Coley brickyard*—now converted into a Recreation ground. The "Bottom bed" contained numerous shells of *Ostrea bellovacina* and some other fossils. The following are in the collection of Mr. Herries:

Odontaspis (Lamna) contortidens.	*Tellina ?*
Pycnodus.	*Panopæa.*
Cardium (large sp.).	*Ostrea.*
Trigonocœlia ?	*Echinus.*
Nucula Bowerbankii.	

Mr. Blake pointed out the locality in the neighbouring workings at Waterloo Kiln, where Mr. Starkie Gardner and the Geological Survey had obtained collections of leaves, etc. Unfortunately the place is now covered with rubbish.

The members having ascended to the top of the working in the side of Bob's Mount, the Basement Bed of the London Clay was carefully examined. It was 12 feet in thickness, the lower half being very fossiliferous, but though the shells are most abundant it was found difficult to obtain many good specimens, the deposit being so sandy. The Directors, however, drew attention to a block lying on the talus, which proved to be a hard portion of the shell-bed formed of a mass of shells in a siliceous matrix, and many shells were obtained from it.

The following fossils were identified by the President:

Odontaspis (Lamna)	*Cardium Laytoni*
Aporrhais Sowerbyi	*Cytherea tenuistriata*
Buccinum	*Modiola elegans*
Fusus errans	*Nucula Bowerbankii*
" *Speyeri*, Desh.	*Ostrea bellovacina*
Natica	*Panopæa intermedia*
Pleurotoma terebralis	*Pectunculus brevirostris*
Trochus	*Ditrupa plana*

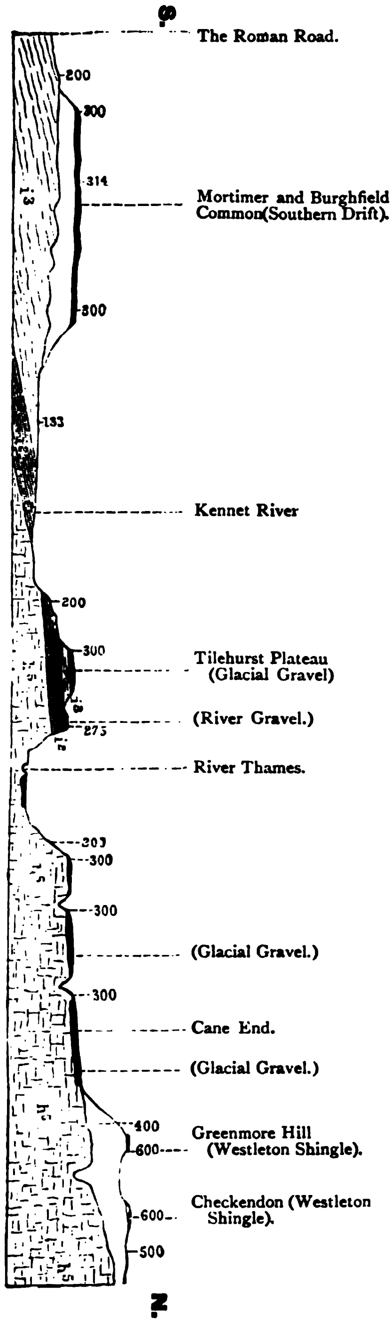
Leaving the Katesgrove and Waterloo Kilns, the party proceeded to a gravel pit near the southern extremity of Bob's Mount, about 210 feet above sea level, and some 94 feet above the Thames at Reading. An exposure of London Clay, consisting of dark bluish-grey and brown clay overlying the stratified Basement Bed was here pointed out.

The gravel, which rests on the London Clay, is composed of:

1. Flints not much rolled or waterworn, probably derived directly from the Chalk.

2. Flints of a brownish colour subangular and waterworn, probably largely from the Southern Drift.

* See "Record of Excursions," p. 270.



SECTION FROM THE ROMAN ROAD NEAR SILCHESTER TO THE HILLS NEAR STOKE ROW.—*H. W. Monckton.*

(Reproduced by permission from *The Quart. Journ. Geol. Soc.*)

i^3 London Clay. i^2 Reading Beds. h^5 Chalk.

Horizontal scale, 2 miles = 1 inch. Vertical scale, 900 feet = 1 inch.

3. Flint pebbles from Eocene pebble beds.
4. Fragments from the Lower Greensand (not common).
5. Quartz pebbles from various sources.
6. Black grit pebbles and boulders of red and brown quartzite, probably from the Triassic conglomerates and pebble beds of central England.

Mr. Monckton drew attention to the diagrammatic section, (p. 413) and said that he agreed with Prof. Prestwich that the Southern Drift was, at least in part, the oldest of the gravels of the district. The Westleton Shingle came next, and then the gravels which are known as Glacial Drift, and finally the River Gravels. The Glacial Drift and the older River Gravels might, however, well be contemporaneous.

The Southern Drift was, he believed, laid down by streams of water flowing off the anticline of the Weald towards the north, and this must have been before the elevation of the northern side of the London Basin, for the present Thames valley cuts across the line of these streams, and we consequently find *débris* from the Lower Greensand of the south in gravels at Hendon and many other places north of the present valley of the Thames.

The gravel at Bob's Mount was almost on the southern boundary of the area over which the boulders from the Triassic Beds were distributed.

The spot having been pointed out where the pot containing Roman coins—now in the Reading Museum—had recently been found in the gravel, the party walked about one and a-half miles eastward to Mock Beggars Brickyard, near Earley, where the Basement Bed of the London Clay and the underlying mottled clays of the Reading Beds were exposed. The Basement Bed of the London Clay is about the same thickness here as at Bob's Mount, namely, 12 feet, but is fossiliferous throughout; whereas at Bob's Mount, above Katesgrove Kiln, it appears to be fossiliferous only in the lower half. Septarian nodules of argillaceous limestone, containing many shells and much lignite and iron pyrites, were observed in the bed, and the annelid *Ditrupa plana* was found to be exceedingly abundant in the lower part.

The President identified the following fossils:

Natica	*Ostrea*
Cytherea ?	*Modiola elegans*
Cardium Edwardsi	*Ditrupa plana*
Pectunculus	

Notwithstanding the wet condition of the beds, many fossils were collected, and the party then returned by tram to Reading, partook of tea at the Vastern Hotel, and returned to London by the 8.20 train, arriving at Paddington at 9.5 p.m.

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New Ordnance Survey Map, Sheet 268.

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1893. MONCKTON, H. W.—"Boulders, etc., from Glacial Drift in Gravels South of the Thames." *Quart. Journ. Geol. Soc.*, vol. xlix, p. 308.

EXCURSION TO HITCHIN.

SATURDAY, 20TH JUNE, 1896.

Directors: WILLIAM HILL, F.G.S., AND HORACE W. MONCKTON, F.L.S., F.G.S.

Excursion Secretary: A. C. YOUNG.

(*Report by* THE DIRECTORS.)

THE members assembled at Hitchin Station at about half-past two in the afternoon, and, starting under the direction of Mr. Hill, they walked northwards along the side of the Great Northern Railway for some distance, and then turned to the right, along a tram line, to Messrs. Ransom's Lime Works, near Grove Mill.

Here a good section in Chalk was seen, and Mr. Hill briefly explained its features, and pointed out the zone of *Belemnitella plena*, the upper limit of the Lower Chalk, and the overlying Melbourn Rock, a small part of which is seen at the top of the pit. A search for fossils followed, but was not very successful.

The party then returned to Hitchin Station, and visited the large chalk quarry, so well known to travellers by the Great Northern Railway, and a part of which was figured in the *Quarterly Journal of the Geological Society* for 1866.* Mr. Hill

* Vol. xxii, p. 566.

said that the horizon was the base of the Middle Chalk, so that the chalk seen at the level of the railway forms practically a continuous section with that at Grove Mill.

The chalk is overlain by Drift consisting of sand, chalk rubble, and gravel well stratified, though the stratification is very irregular in places. Mr. Hill pointed out a place where clay with ice-scratched stones occurs, and drew attention to a very coarse gravel with boulders of a great variety of rocks at the bottom of the Drift. This Drift is of Glacial age, and possibly the clayey bed represents the Boulder Clay.

Leaving the railway at the Benslow Bridge, the party walked over Higbury Hill to the high ground east of the town of Hitchin, which is covered by a sheet of Glacial Gravel. The surface is not very level, and is in places a little above, and in others a little below, the 300 feet contour line. From a commanding position on this high ground Mr. Hill pointed out the main features of the district, and drew attention more especially to the situation of the brickfield, where a freshwater formation occurs, which was to be visited later on.

Turning into a pit in the Glacial Drift it was seen to be composed of an upper bed of a clayey character, reminding one somewhat of the clay bed seen at Hendon on April 25th last, and marked bed *b* in Figs. 2 and 3 on pages 328, 329 *ante*, and of a lower bed of stratified sand and gravel, with much current bedding in places. This gravel belongs to the Glacial Drift, and Mr. Monckton remarked that when one considers how extensive the Glacial Gravels are in the midland and eastern counties of England, it is strange that the highest authorities should be unable to agree whether they are of marine or of freshwater origin.

The gravel is composed very largely of flint. There are a good many pebbles of white chalk, and also boulders of all sorts of rock. On a former occasion Mr. Monckton found a pebble of carboniferous limestone with *Spirifera trigonalis* in this pit, and a pebble of red chalk in an adjoining pit.

From the gravel pit the party walked to Mr. W. Jeeves' brickfield, where a good section was pointed out by Mr. Hill. The level of the surface of the ground is about 235 feet above ordnance datum, and the following beds (in descending order) were exposed.

1. BRICK-EARTH of a reddish-brown colour with a few stones scattered through it. 20 ft.

2. THE FRESHWATER BED. Soft calcareous loam of a light colour, from brown to almost white, which has been found in other parts of the brickfield to pass down into a dark grey or almost black deposit, fairly evenly stratified.

3. GRAVEL, composed of flint, chalk pebbles, and a great variety of rocks all more or less rolled and waterworn. The gravel is well stratified, and often current-bedded.

Numerous flint implements have been found in the brick-earth, bed 1 of the above section, and also mammalian remains, which have yet to be determined.

The following is a list of fossils from the Freshwater Bed.

MAMMALIA.

In possession of Mr. W. Ransom, Hitchin.

Ursus.
Cervus elaphus.
Rhinoceros.

MOLLUSCA.

Identified by the President, E. T. Newton, F.R.S. Those with a star (*) have since been added by Mr. A. S. Kennard.

Bythinia tentaculata.
Limnæa auricularia.
Limnæa peregra.
Planorbis carinatus.
Planorbis complanatus, Linn. (=*marginatus*, Drap.).
**Planorbis spirorbis.*
Valvata cristata.
Valvata piscinalis.
* *Velletia (Ancylus) lacustris.*
Anodonta cygnæa (?).
Sphærium corneum.

OSTRACODA.

Identified by Professor T. Rupert Jones, F.R.S., and recorded by him: †

Candona candida.
Cypris Browniana.
Cypris incongruens.
Cypris reptans.

PLANTÆ.

Chara (stems and fruits).

Mr. Hill stated that an elephant's tooth was found a year or two ago in the gravel beneath the Freshwater Bed. The gravel contains numerous boulders with fossils from various formations, and the following were found by members of the Association on the present occasion:

† *Geol. Mag.*, dec. III, vol. iv, p. 459 (Sept. 1887).

Derived fossils from Gravel which underlies Freshwater Deposit—

Cardinia concinna (= *C. lanceolata*)	Lias.
Pleuromya costata	Lower Lias.
Pleuromya crassa	Lower Lias.
Serpula tetragona ?	Cornbrash.
Gryphæa bilobata ?	Kellaway's Rock.

Referring to the Geological Survey Map, Sheet 46 N.E. Drift Edition, Mr. Monckton observed that the Drift was divided into eight divisions, two of which, the "clay with flints" and the "loam" associated with it, did not occur near the locality visited, and consequently did not call for attention just then. The other divisions were, beginning with the newest:

1. Alluvium.
2. Loam.
3. River Gravel.
4. Glacial Loam.
5. Glacial Boulder Clay.
6. Glacial Gravel.

According to the map, the brick-earth before them was classed with the loam of Glacial age (No. 4 of the above list), and he supposed therefore that if the Boulder Clay had been present, it would have come in between the Freshwater Bed and the underlying gravel.

Unfortunately the Boulder Clay is not present in the brickfield, though it has been mapped about a mile away, near Great Wymondley, at a level of about 270 feet O.D. The level of the brick-earth ranges from about 290 feet O.D. on Hitchin Hill, to about 235 feet O.D. at the Folly. The nearest patches of River Gravel mapped are along the course of the River Purwell, at levels of about 183 to 190 feet O.D.

In the absence of definite evidence, Mr. Monckton thought it was still an open question whether the Brick-earth and Freshwater Bed ought not to be classed with the "Loam" No. 2 of the list given above, instead of with the Glacial Loam. He reminded the members of a somewhat similar bed at Mundesley, which was visited by the Association on April 1st, 1893.* That bed was at one time supposed to be intercalated in the Boulder Clay, but it is now held to be an alluvial deposit newer than the Glacial Beds.†

The celebrated Freshwater Deposit at Hoxne also bears some resemblance to the Hitchin bed. In it many flint implements have been found, and it was at one time classed with the Glacial Series, but it is described by Messrs. Whitaker and Dalton as post-glacial.‡

A bed of brick-earth with freshwater shells, at Rickinghall

* See *Proc. Geol. Assoc.*, vol. xiii, p. 59.

† C. Reid, "Geology of the Country Round Cromer" 1882, *Mem. Geol. Survey*, p. 118.

‡ See Lyell, *Antiquity of Man*, 4th Edition, 1873, p. 219, and Whitaker and Dalton "The Country round Halesworth and Harleston," 1887, *Mem. Geol. Survey*, p. 27.

Superior, has been described by Mr. F. J. Bennett, F.G.S., as occurring below Boulder Clay,* and it is pretty obvious that the classification of the numerous beds of brick-earth and loam in the east of England is by no means free from difficulties.†

Some time was spent collecting from the Freshwater Deposit, but the shells, though very abundant, were found to be most fragile.

Leaving the section, the party walked into Hitchin, other sections in the brickfields being pointed out by Mr. Hill in passing, and from the gravel of one of these two other forms of derived fossils were obtained, namely, *Sternbergia*, a Coal Measure plant, and *Avicula inæquivalvis*, from the Kellaways Rock.

An excellent tea was provided at the Sun Hotel, and after full justice had been done to it the President proposed a vote of thanks to Mr. Hill, and to the gentlemen who had assisted him in arranging the excursion. It was carried unanimously, and Mr. Monckton observed that, curious to say, the Association had not visited Hitchin before; but after the successful afternoon which all present seemed to have enjoyed, he thought it would not be long before the visit was repeated.

Mr. A. E. Salter said it was interesting to note, in connection with the drift deposits seen near Hitchin, that the town is situated at the northern entrance of one of the few gaps which penetrate the chalk hills to the north and north-west of London. South of this gap gravel deposits are found at heights varying from 460 to 300 ft. O.D., the constituents of which increase in complexity as the height decreases, till in the lower ones undoubted glacial materials are found.‡

NOTE.—Mr. Salter writes that he was struck by the apparent absence of older rocks like schists, granite, etc., which have been found farther down the gap, *i.e.*, at Finchley. He found, moreover, only one doubtful liver-coloured quartzite. I am inclined to think that the apparent absence or scarcity of igneous rocks in these gravels is largely due to the fact that those rocks decay easily. A short time ago I took a boulder about 6 ins. in diameter from the side of a gravel pit a little north of Hitchin, and on throwing it down it broke up into small fragments. It appeared to have been granite. H. W. M., 1st July, 1896.

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1887. H. B. WOODWARD.—"Geology of England and Wales," 2nd edition.

* "Geology of Country round Diss, etc.," 1884, *Mem. Geol. Survey*, p. 12.
† See H. B. Woodward, "Geology of Country round Norwich," 1881, *Mem. Geol. Survey*, p. 110.
‡ For further details on this subject see Mr. Salter's paper, this vol., *ante*, p. 389.

EXCURSION TO POTTER'S BAR AND HATFIELD.

SATURDAY, 4TH JULY, 1896.

Director: A. E. SALTER, B. SC.

Excursion Secretary: A. C. YOUNG.

(*Report by* THE DIRECTOR.)

THE party left King's Cross Suburban Station at 2.30 p.m. for Potter's Bar. *En route* the high ground to the west, between Oakleigh Park and New Barnet, was pointed out as being capped with Glacial drift, at Whetstone about 300 feet O.D.; and Pebbly gravel at High Barnet 400 feet. A deep boring just outside Potter's Bar Station showed that only a slight covering of Tertiary deposits lie over the chalk at this spot. Mimmshall Wood, 424 feet, was reached after a walk of about two miles, and the party examined minutely one of the numerous sections to be found in this wood. The simple character of the constituents of the gravel was very apparent. The Director stated that the highest gravels of this district, such as those at Stanmore, 500 feet, Barnet Gate, 424 feet, consisted chiefly of flint *débris* in various forms, together with very small quantities of quartz or other rocks. At slightly lower levels, *e.g.*, High Barnet, 400 feet, Shenley, and the section then before them, quartz was present far more abundantly, and was also of several kinds. Beside this and flints, pieces of other rocks were not unfrequently found, *e.g.*, jasper, lydian stones, sandstone pebbles, etc., a selection of which, found on the spot, was shown to the party. Two pieces showed markings of crinoid stems, and appeared to be of Carboniferous age. At lower elevations the constituents become still more complex, until at last deposits were reached of a distinctly glacial type. Examples would be forthcoming later. By means of a contour map of the district, the Director pointed out that a series of these gravels is found around the gap in the Chalk downs to the north in the neighbourhood of Hitchin and Stevenage, and suggests that they have all come from that direction. Similar gravels are found arranged round other gaps in the Chalk downs. Descending to the 300 feet contour, a pit in glacial gravel was pointed out, and its contents contrasted with that of the gravel on the hill. After a walk of about three miles Bell Bar was reached, and the gravel there at 369 feet O.D. examined. This much larger deposit contains pebbles of a very varied description, some of which are extremely puzzling to account for. Quartz of various kinds and sizes was abundant, and lydian stones, glassy and liver-coloured quartzites, were soon procured. Some pieces of dark chert, found here and in similar deposits, have been examined by Dr. G. J. Hinde, who has found that

they contain casts of Radiolaria apparently of Carboniferous age. At Bayford, Hertford Heath, Great Easton, in Essex, similar deposits are found. From the discussion which followed it was very evident that much remains yet to be cleared up with regard to the origin of these gravels. A pleasant walk through Hatfield Park, followed by tea at the "Salisbury Arms," at which the Director received a hearty vote of thanks, brought what it is hoped was an interesting excursion to a close.

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Ordnance Map, New Series, Sheet 239.

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1892. WHITE, H. J. O.—"Notes on the Westleton Beds near Henley-on-Thames." *Proc. Geol Assoc.*, vol. xii, p. 379.
1895. ————————"On the . . . Westleton and Glacial Gravels in parts of Oxfordshire and Berkshire." *Proc. Geol. Assoc.*, vol. xiv, p. 11.

EXCURSION TO THE NEW RAILWAY AT CATESBY, NORTHAMPTONSHIRE.

SATURDAY, 11TH JULY, 1896.

Director: BEEBY THOMPSON, F.C.S., F.G.S.

Excursion Secretary: R. S. HERRIES, F.G.S.

[*Report by* THE DIRECTOR.]

THE object of the excursion was to inspect the various sections exposed in the cuttings, and examine the material thrown out from the tunnel, in the new extension to London branch of the Manchester, Sheffield, and Lincolnshire Railway, now in course of construction, between Catesby and the point where it crosses the East and West Junction Railway, in all about six miles. Permission to do so was kindly given by the engineers, Messrs. Sir Douglas and Francis Fox, and the excursion was much facilitated by the courtesy of the contractors, Messrs. Oliver and Sons, in placing an engine and truck at the disposal of the party to get over the less interesting parts of the line more quickly.

The members who availed themselves of the excursion arrived at Byfield Station on the East and West Junction Railway about twelve o'clock, and from thence walked to where the new Manchester, Sheffield, and Lincolnshire Railway crosses the older one, near to Woodford. A part of the journey from here

was made under the guidance of the resident engineer, Mr. D. L. Hutchison.

Short halts were made, at S (Plate XIV), to see the Upper Lias Clay; R, the extensive Drift Gravels; P to Q, the Cephalopoda beds at the base of the Upper Lias; K, the position of a slipped mass of Lower Estuarine beds (white sands); G, the faulted junction of Upper and Middle Lias; F, Drift-beds; E, Reversed fault; C to D, Lower Margaritatus zone beds; B, Clays of the Capricornus zone. Also a small section showing the lowest beds of the Upper Lias resting on the Marlstone Rock-bed, close to Catesby, was visited, by kind permission of H. A. Attenborough, Esq., of Catesby House, who had a quarryman present to assist the visitors in procuring fossils.

From Catesby the party walked to Daventry, where a meat tea was provided at the "Wheat Sheaf" Hotel, and the homeward journey was commenced from there by the 7.5 train.

The new railway runs very nearly north and south, inclining a little to the west in a northerly direction. The total rise in the ground surface from south to north, in a little over five miles, to near Catesby, is 125 feet, and then in less than a mile, where the line cuts the Marlstone escarpment diagonally (see diagram), there is a drop of 163 feet; hence the necessity for tunneling.

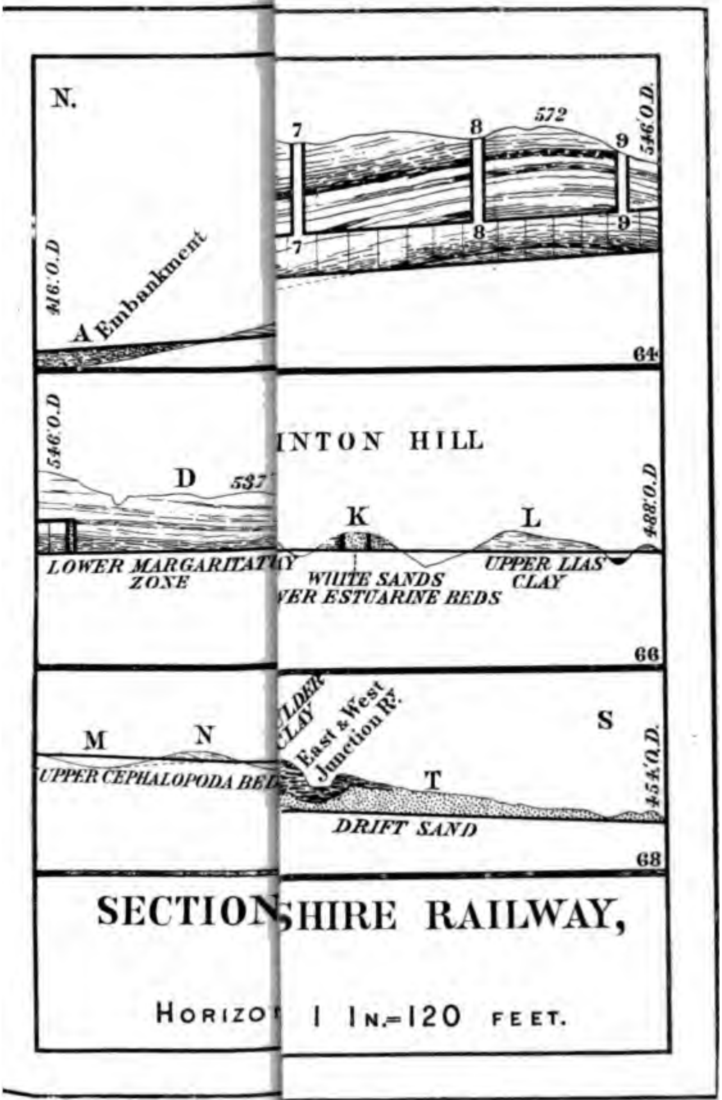
Besides the rise of the ground, there is a general rise of the geological formations composing it of quite 28 feet per mile, the top of the Marlstone at C being almost exactly 100 feet higher than at Q, in a distance of $3\frac{9}{17}$ miles. It is quite possible, even probable, that the gradient increases towards B; it is also necessary to assume a considerable uplift between C and D to account for the observed positions of the beds.

It will be noted in the diagram that the line rises from Catesby towards Charwelton, and then drops again; the rise is 30 feet per mile—1 in 176. The entire length of the tunnel is nearly 3,000 yards. There are nine shafts altogether, one formerly at the end B was converted into an open working.

Description of the Sections.

Lower Lias.

Capricornus Zone.—The lowest formation met with is the Capricornus Zone of the Lower Lias (Geological Survey Divisions), and this is only seen at the open working at B, Shaft No. 1, and the tip at and beyond A. It is a stiff blue clay, very homogeneous, and contains very many fossils beautifully preserved, many of the Lamellibranchs having the original coloured bands on them, and most of the Capricornus Ammonites are brilliantly coloured when first exposed. Perhaps the most abundant fossil is *Avicula inæqui-*


N.
7
8
572
9
546' O.D.
416' O.D.
A Embankment
64
546' O.D
D
537
INTON HILL
K
L
488' O.D
LOWER MARGARITATUS ZONE
WHITE SANDS
VER ESTUARINE BEDS
UPPER LIAS CLAY
66
M
N
LDER CLAY
East & West Junction Ry.
S
UPPER CEPHALOPODA BED
T
454' O.D.
DRIFT SAND
68
SECTION SHIRE RAILWAY,
HORIZO 1 IN.=120 FEET.

face p. 427.

valvis, but it is difficult to get and preserve good specimens of this or any of the larger fossils. (See list.)

JUNCTION BED OF LOWER AND MIDDLE LIAS.

Ever since the railway was commenced I have hoped that the various cuttings would enable me to determine the thickness, as well as examine the character, of the beds between the well recognised Margaritatus Zone of the county and the Capricornus Zone, no such opportunity having occurred to me before. About Market Harborough (Little Bowden) and again in the Callender brook, near to Cottesbrook, I thought I had discovered the boundary of the two zones as an oyster-bed containing well rounded and water-worn nodules. It is only since the visit of the Association to Catesby that I have found such a nodular bed in the masses of clay put out from No. 3 shaft. The nodules are abundant, mostly rather small, not very hard, some cracked in all directions and cemented again by iron pyrites, etc ; water-worn, some discoloured, others bleached ; they are mostly bored by *Lithodomi* (?), and a few are covered with polyzoa of a form quite new to me. There are some oysters associated with the nodules, but the most characteristic fossil is *Pecten equivalvis*, fairly large specimens being quite abundant.

MIDDLE LIAS.

LOWER MARGARITATUS ZONE.—Above the nodule bed in Shaft No. 3, and from all shafts south of this, as also from the cutting D E, only micaceous sands, sandy clays, and sandstones or limestones, are cut through. These beds have never been well examined before in Northamptonshire, nor their thickness determined, hence a fairly full description seems desirable.

Soft material.—The great mass of the material brought out of the tunnel from Shafts 3 to 9, and therefore from a good depth, is bluish-grey, sandy and highly micaceous clay, approximating to a sand in many places, weathering very light coloured in a short time, almost as it dries, though when wetted it is almost as dark as the Capricornus clays.

Hard beds.—There are numerous continuous hard beds in the clay, of the same colour, which effervesce considerably with acids, whereas the great mass of the clay does so very little. These continuous bands may be seen at D and H, and great quantities have been used all along the line for drains and ballast, after breaking. In addition to the more continuous bands great masses of indurated rock occur here and there in isolated patches.

Colour.—At H the whole Middle Lias, whilst retaining the same lithological characters as in other places, is all of a light

ruddy colour; also the whole of the section from the tunnel to E is of the same ruddy colour, except near the bottom, where there are some blue argillaceous layers which throw out a little water Evidently the ruddy colour extends downwards as far as oxygenated water could pass, and to this is due the change of colour. In the early stages of the work, before the shafts were sunk to their full depth, the same ruddy material was brought up from several, I noticed it particularly at Shaft No. 3, when they informed me that it was 80 feet deep. This is quite consistent with the depth to which, in some of the shafts, they were troubled with water.

Fossils.—These beds cannot be described as very fossiliferous, though through frequent examination I have managed to make up a tolerably long list. Some of the hard layers are literally covered with fossils of two or three species along certain lines, but these are mostly fine-grained slaty beds. The most characteristic fossils are *Ammonites Engelhardti*, D'Orb., *A. Algovianum*, Oppel, and *Cryptænia expansa. Pecten liasinus*, *Avicula inæquivalvis*, and *Protocardium truncatum* are abundant in places, but not characteristic as regards numbers or species.

Thickness.—I have reason to believe that these Lower Margaritatus zone beds commence at 52 feet from the surface in Shaft No. 4, and since the beds and the ground both rise to the north, I think this would be pretty accurate for Shaft No. 3, and as the shaft merges into the tunnel at 93 feet, and the tunnel is 30 feet high, it follows that these beds must be between 41 and 70 feet thick; I expect about 65 feet will prove to be near the mark.*

JUNCTION BED BETWEEN LOWER MARGARITATUS ZONE AND UPPER MARGARITATUS ZONE.—The lowest bed of the true "Margaritatus" Zone† is mostly, and over a very large area, a hard, mottled rock, green with ruddy inclusions, and containing water-worn nodules or pebbles, much comminuted shell, and some good fossils. It is also a good water-bearing bed. This was almost certainly passed through in making Shafts 1 to 8. Such a rock was described to me as having been encountered in Shaft No. 4 at a depth of 48 feet, where it was 4 feet thick. I had previously found it in the material from a trial-hole at C, very near to Shaft 4, where it had the following characters:—A hard, mottled stone, yellow and red and green, green predominating, containing rolled and worn micaceous nodules and fossils, and much comminuted shell. The following fossils were found fairly perfect:

* Mr. Hutchison has been kind enough to ascertain for me the depth of the nodule-bed in the workings near Shaft No. 3, and gives it as 466·4 feet, O.D. At Shaft No. 3 itself it would no doubt be a little lower, so that 57 feet would appear to be a near approximation to the thickness.

† See *The Middle Lias of Northamptonshire*, by Beeby Thompson, F.G.S., F.C.S. Bed "L" pages 8 and 10 to 12.

Belemnites.	*Cardita multicostata.*
Ostrea submargaritacea (large).	*Gresslya.*
Pecten equivalvis (large).	*Cardinia* (very numerous).

At I, forming the base of the railway, a ruddy stone was found, almost made up of shells, mostly comminuted or greatly water-worn, also containing water-worn nodules, some rather large. The fossils obtained or identified were :

Belemnites.	*Astarte.*
Gasteropods.	*Cardinia concinna* (large).
Ostrea submargaritacea.	„ *crassissima*? (many).
„ *cymbium.*	*Serpulæ.*
Cardita multicostata.	

I consider this is the basement bed of the Upper Margaritatus Zone, lacking its usual green and mottled appearance because quite superficial and so weathered.

This bed did not appear to dip so much as the beds immediately to the north of it (H), which latter must evidently belong to the upper part of the Lower Margaritatus Zone.

UPPER MARGARITATUS ZONE.—This, although certainly cut through in making some or all of the shafts for the tunnel, was nowhere detected along the line, except in the material for a trial hole at C.

SPINATUS ZONE.—The only certain evidence of the Spinatus Zone along this railway was furnished by the top bed, the Marlstone rock-bed. The rock-bed was cut through, under about 5 feet of clay, in Shaft No. 4 (and probably 2, 3, 5, and 6), and had a thickness of about 2 feet 6 inches. It was to be seen at P when making the foundations for a bridge, and from O to Q in making drains (see description of Upper Lias). As already pointed out, it was seen by the members of the Society in the small quarry near Catesby.

TRANSITION BED BETWEEN THE MIDDLE AND UPPER LIAS.

The well-known Transition bed between the Middle and Upper Lias was only to be seen at one place along the line, at P. (See Section below.)

UPPER LIAS.

In all the cuttings from E to S, excepting R, some portion of the Upper Lias was to be seen.

The *Fish-bed* forms the base of the railway almost the whole distance from O to Q.

The "*Serpentinus*" and "*Communis*" *Beds* were well seen in the cutting O, P, Q.

The *Unfossiliferous Beds* were to be seen in part of the same cutting, also at G (?), J, K, L, N, and S.

The "*Leda-ovum*" *Beds*, in part, at E.

The section at P, produced below the line for making foundation for a bridge, well illustrates the development of the lower beds of the Upper Lias and the upper one of the Middle Lias, and hence is given below.

SECTION ON M. S. & L. RAILWAY WHERE ROAD TO HINTON HILL CROSSES IT

UPPER LIAS.

		ft.	in.
Unfossiliferous Beds.	1. Soil and blue clay, getting very ruddy the last 6 inches or so. (These lower beds are always ruddy when rather superficial from the decomposition of iron pyrites	11	6
"Communis" Beds.	2. UPPER CEPHALOPODA-BED.* An argillaceous limestone, soft and ruddy, highly fossiliferous, but fossils easily broken	0	8
	Ammonites bifrons (many). ,, *cornucopia.* ,, *heterophyllus.* ,, *subcarinatus.* ,, *Strangewaysi.* ,, *exaratus.* ,, *Holandrei* (many). ,, *communis* (many). *Nautilus astacoides* ? *Belemnites subtenuis* ? *Trochus duplicatus.* *Nucula Hammeri.* *Astarte.* Etc.		
	3. Variegated Clay, ruddy in places, nowhere very blue, oolitic concretions abundant in parts. Many small Ammonites of the *Stephanoceras* genus	3	0
"Serpentinus" Beds.	4. LOWER CEPHALOPODA-BED. A hard argillaceous limestone, fewer fossils than in the Upper Cephalopoda-bed, but better preserved; thickness variable. Many Ammonites of the "falcifer" or "serpentinus" group. *Ammonites Strangewaysi* (very large) . . . . . . 6 in. to	0	9
	5. Dark blue clay, but very red along joints . 2 ft. 6 in. to	3	0
	6. CEPHALOPODA-BED (inconstant one). A bed so very like No. 2 in appearance that it is often difficult to tell one from the other at first, but this one contains no *A. bifrons*, and the *Harpoceras* Ammonites in it are larger and more numerous . . . . 6 in. to	0	8
	(This bed often merges into the Fish-bed below; at other times it seems to be rather a part of the beds above.) *Ammonites Strangewaysi*, ,, *heterophyllus*, ,, *cornucopia*, *Nautilus astacoides* } all very large.		
Fish Beds.	7. Paper Shale, with flattened Ammonites of the "falcifer" group	0	2
	8. FISH-BED. A grey, highly pyritous bed; some parts, however, like the normal fish-bed	0	4

BASE OF UPPER LIAS.

		ft.	in.
"Transition" Bed.	9. Grey Marl, here and there clay, in other places red sand. Less fossiliferous than usual here . .	0	2

* This bed also seen in excavation for drain at M, about 10 feet below line.

MIDDLE LIAS.

		ft. in.
"Spinatus" Zone.	10. ROCK-BED. A hard grey stone, with red joints, containing:	1 6
	Rhynchonella tetrahedra (many)	
	Terebratula punctata	
	Waldheimia resupinata	
	and in lower part only:	
	Pholadomya lunulata	
	Gresslya intermedia.	
	11. Clay, with masses of comminuted shell.	

INFERIOR OOLITE.

Naturally, no Inferior Oolite occurs *in situ* along this line, yet at "K" a considerable patch of the white sands of the Lower Estuarine Beds was passed through some 30 yards in length. There can be little doubt that this is the remains of a very old slip from the adjacent Hinton Hill and not a "fault" proper, for it rests on nearly the lowest beds of the Upper Lias, although its proper position is at the top of the Northampton Sand. This explanation is rendered the more probable in that the vertical plant markings so characteristic of the bed when *in situ* are here horizontal, or nearly so. So far as I am aware, there are no white sands left in their normal position—that is, on the tops of the hills over the ironstone beds—anywhere in the neighbourhood; there is not a trace on Hinton Hill itself. The slip must have been about 120 feet or more.

DRIFT BEDS.

The drift beds consist of sand, gravel, and Boulder Clay. For the whole course of the line from A to F the surface of the ground is practically free from drift of any kind.

At F the Upper Lias clay is replaced by a mass of stratified sand and gravel irregularly disposed in layers, the finer material constituting the lower part chiefly. Between the two roads marked on the diagram there are extensive gravel deposits at the side of the railway, which are worked for ballast. The cutting R is entirely in a similar gravel, also worked for ballast.

At S the unfossiliferous clays of the Upper Lias are overlain, and to the south entirely cut off by "drift" beds, as shown in the diagram. Resting on the clay is a fine ruddy sand, mostly well stratified, intercalated here and there with blue clay, and greatly resembling the true Middle Lias beds in the lower part of the section at D. It is remarkably free from stones or larger fragments, except where a patch of true gravel occurs. The thickness of the sand varies, but where it rests on Upper Lias clay is about 10 feet.

Boulder Clay rests irregularly on this sand and makes up the difference of depth. It is somewhat singular that no sand or gravel occurs on the top of the Lias clay in an equally deep and

quite contiguous cutting leading on to the East and West Junction Railway.

FAULTS.

REVERSED FAULT.—The fault shown at E is interesting because the lower beds (Middle Lias) rest upon the slope of higher beds (Upper Lias), thus constituting a reversed fault. Assuming the beds in juxtaposition at the top of the section to be the highest of the Lower Margaritatus zone and the lowest of the Leda-ovum beds of the Upper Lias, the throw of the fault would be about 130 feet, and it cannot be less.

THE NORMAL FAULT shown at G, just about half-a-mile farther south, may be, and probably is, a part of the former, though for most of the distance between no Upper Lias clay is to be seen owing to the drift valley running across it. In this case I do not know the zone of the Upper Lias abutting against the Middle Lias, though it is probably some part of the unfossiliferous zone.

The hade in each case must be just about the same, for in the one at E, measured on a slope of 1 in 3 it gave 23°, whereas in the one at G, measured on a slope of 1 in $2\frac{1}{2}$, it gave 25°.

It is most difficult to account for this (or these) fault because on each side of it the Middle Lias beds seem to be lifted, as though the clay had come up from below, whereas its proper position is much above.

The Middle Lias beds at H have an inclination on the slope of about 6° to within a short distance of the fault, and then a somewhat greater uplift.

List of Fossils from the Capricornus Zone and Lower part of the Margaritatus Zone.

	Capricornus Zone.	Lower Margaritatus Zone.
Ammonites capricornus (many)	×	
,, *fimbriatus*	×	
,, *Engelhardti* (fair number) .		×
,, *Margaritatus* (one ?) . .		×
,, *Algovianum*, Oppel. (several) .		×
,, *trivialis*, Simp., var. *lineatus* .		×
Nautilus sp.		×
Belemnites clavellatus	×	×
,, sp. ?	×	×
,, *Milleri* ?		×
Actæonina marginata	×	
Cryptænia expansa (one from lower beds, many from higher)	×	×
Chemnitzia transversa (many) . . .	×	

	Capricornus Zone.	Lower Margaritatus Zone.
Turritella Dunkeri (one)	×	
Turbo cyclostoma		×
Eucyclus imbricatus	×	
,, sp. ?	×	
Dentalium elongatum ?	×	
Ostrea sp. ?	×	×
,, *cymbium*, var. *depressa*		×
Anomia numismalis (many)	×	
Pecten equivalvis	×	×
,, *lunularis* = *liasinus* (great numbers)	×	×
Limea acuticosta	×	×
Plicatula spinosa	×	
Monotis cygnipes	×	
,, *inæquivalvis* (enormously abundant in Cap. Zone)	×	×
Inoceramus ventricosus (one)	×	
,, sp. ?	×	
Pinna sp. ? (very large)	×	
Modiola scalprum	×	×
,, *numismalis*		×
Arca elongata	×	
Macrodon intermedius, Simp. = *Arca numismalis*, Tate (many in Cap. Zone)	×	×
Leda galathea = *Nucula inflexa* (abundant in Cap. Zone)	×	×
,, *graphica*	×	×
,, *minor*	×	×
Pholadomya ambigua	×	×
,, *Simpsoni* ?		×
,, *Beyrichii*, Schl. ?	×	
Astarte striato-sulcata		×
Cardita multicostata	×	×
Cypricardia cucullata		×
Hippopodium ponderosum	×	×
Protocardium truncatum	×	×
Unicardium cardioides (many)	×	
Goniomya heteropleura	×	
,, *hybrida*	×	×
Pleuromya costata	×	×
Cardinia antiqua (one)		×
Rhynchonella calcicosta ?	×	× ?
,, *lineata*		×
Bairdia liassica	×	
Ditrypa circinata	×	×
,, *quinquesulcata*		×
Cidaris ? spines	×	

	Capricornus Zone.	Lower Margaritatus Zone.
Ophioderma ? (numerous fragments)	×	
Extracrinus subangularis ?	×	
Pentacrinus scalaris ?	×	
Cristellaria	×	
Frondicularia	×	
Dentalina	×	
Fucoids		×

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EXCURSION TO NOTTINGHAM AND LEICESTER.

SATURDAY, 18TH JULY, 1896.

Directors: G. ELMSLEY COKE (late Lieutenant R.N.), Professor J. W. CARR, M.A., F.G.S., and W. W. WATTS, M.A., F.G.S.

Excursion Secretary: A. C. YOUNG.

(*Report by* THE DIRECTORS.)

THE members arrived at Nottingham about noon, and after a hurried luncheon at the railway station, made their way to the meadows siding of the new line to London of the Manchester, Sheffield, and Lincolnshire Railway Company. Here they were met by Mr. Edward Parry, the engineer of the northern section of the line, through whose kindness a contractor's engine and two comfortably-furnished trucks had been provided to convey the party alone the line. The first stoppage was made at Ruddington, four miles south of Nottingham, the journey, so far, having been over the alluvial deposits of the Trent Valley and the Keuper Marls.

The object of this halt was to allow an inspection of the Ruddington boring, which was commenced in June, 1895, by the Vivian Diamond Boring Company, with the object of proving if

workable coal exists under the Ruddington Estate, belonging to the Paget Trustees. After penetrating 466 feet of Keuper and 218 feet of Bunter the Coal Measures were reached, towards the end of September, at a depth of 684 feet from the surface. Early in November a seam of coal was proved at a depth of 942 feet, and it was found possible, by comparison with other local sections, to obtain some idea of its horizon. The section agreed with one only, and that was a trial below the Kilburn coal seam made by the late Mr. North near Stanton Gate Station. At a depth of 1,122 feet sandstones were met with, gradually becoming coarser, until at 1,152 feet they changed to a coarse gritstone, which continued to 1,263 feet, when the finer sandstones and shales again set in. The members were shown the cores to the depth of 1,366 feet, and appeared to agree with the suggestion of the Directors that the coarse gritstone represents the Millstone Grit. It is intended to continue the boring until no question can arise as to the true horizon. The boring machinery was explained by the foreman borer, and after an interesting half-hour had been spent, the journey southwards was resumed.

Some deep cuttings in the Keuper Marls were traversed on the way, and the train next drew up near East Leake, about nine miles from Nottingham. Here the ground rises into a low range of hills, capped by the Lower Lias limestones, and through which the railway line passes in a tunnel. At the northern end of this tunnel a most interesting section is exposed. The Upper Keuper Marls are seen passing up into the pale-coloured "tea-green marls"—the passage-beds between the Keuper and the Rhætic. On these again rest the blackish, thinly-laminated "paper-shales" of the *Avicula contorta* series. The junction between these two series is very sharply defined, not only by the marked difference in colour, but also by the characteristic weathering, the tea-green marls breaking up into cuboidal "dice," while the black shales split into thin papery flakes.

Above the paper-shales is a band of nodular lumps of limestone, containing the characteristic fossil *Estheria minuta*; and, finally, the top of the ridge is formed by the limestone and clays of the Lower Lias.

The various parts of the section were examined with much interest, and some of the bolder members of the party mounted the steep slopes of the cutting in search of fossils, a few characteristic forms being obtained in the short time allowed. Moving on over the ridge of the hill to the southern end of the tunnel the Lias limestones and shales were seen beautifully exposed in the sides of the cutting, but the feature which excited most interest was a fault which here brings down the Lias alongside the Keuper. On this occasion the actual line of the fault was somewhat obscured by rain wash; but when freshly exposed in making the cutting the contrast between the pale bluish-grey

of the Lias limestone and the deep red of the Keuper Marls was very striking.

The members now boarded a second train which was in waiting, and were carried rapidly on to Loughborough, passing on the way some remarkable sections of gravelly drift, here and there strongly contorted. Time did not, however, allow of a stop being made to examine these sections. At Loughborough a gap in the line necessitated another "change," and the next halt was made at Buddon Wood, in Charnwood Forest, about five miles south of Loughborough. Here the party was met by Mr. Watts, under whose guidance a pleasant half-hour was spent by the majority of the members in examining the small knolls of Charnwood rocks which rise like islands through the Triassic plain, the rest of the party meanwhile going off, under the guidance of Mr. Parry, to inspect the works of the immense impounding reservoir, which has recently been constructed here by the Leicester Corporation to augment the water supply of that town. Within a week or two of the visit of the Association the reservoir was filled with water, and part of the ground visited by the party, under Mr. Watts's guidance, was permanently submerged.

The attention of the geological party was first drawn to the granitite of Brazil Wood, and it was pointed out that it was somewhat more basic in composition than that of Mount Sorrel and Buddon Wood. Mr. Watts stated that in the trench now occupied by the higher dam of the reservoir numerous dykes of an even more basic rock were seen to be intrusive into the purple micaceous and garnetiferous slate, or "hornfels," which here comes into contact with the granite edge. He, therefore, thought it not improbable that the "diorite" of the knoll outside the Wood, which is shortly to be submerged under the water of the reservoir, was a still more basic marginal phase of the granite, although it was not possible to prove this with certainty, as the boss of "diorite" was isolated, and no rock precisely similar had been met with in the trench. The party then visited the quarry in the "hornfels," in which granite dykes were to be seen, and pieces of the rock with mica and garnets, together with contact specimens, were collected. On the southern side of the Wood rather less altered slates were seen, but Mr. Watts did not feel confident that they could be definitely correlated with those of Swithland and Groby, on account of the metamorphism they had undergone. Finally, the knoll of "diorite" was visited, and in reply to some remarks by Mr. Paull, Mr. Watts expressed his substantial agreement with the results of Messrs. Hill and Bonney, and his great admiration for the excellent work done by those observers in Charnwood Forest.

Again entering the train the journey was continued to Leicester, the route passing almost entirely through cuttings, often of great depth, in the Glacial Drift, in which erratic

blocks were abundant. Occasionally the sands showed strong current-bedding, and in places were much contorted. It was much to be regretted that no stoppage could be made to more fully examine these remarkable deposits. A momentary halt was made at Belgrave, just outside Leicester, to allow some of the party to inspect a remarkable example of a railway bridge built on the principle of a "double skew," the only one of its kind, it was stated, on this line. Soon afterwards the party left the train, and made the rest of the journey into Leicester on foot, meeting together for tea at about half-past five at the Midland Station.

A hearty vote of thanks was afterwards passed to Mr. Parry for his excellent railway arrangements, and also to the contractors, who themselves took personal supervision of the journey over their respective contracts.

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(For a full bibliography see "The Geology and Natural History of Nottinghamshire," edited by J. W. Carr, Nottingham, 1893.)

LONG EXCURSION TO WEST SOMERSET AND NORTH DEVON.

MONDAY, 27TH JULY, TO SATURDAY, 1ST AUGUST, 1896.

Directors: H. HICKS, M.D., F.R.S., PRESIDENT OF THE GEOLOGICAL SOCIETY, REV. H. H. WINWOOD, M.A., F.G.S., AND J. G. HAMLING, F.G.S.

Excursion Secretary: R. S. HERRIES, F.G.S.

(*Report by* R. S. HERRIES; *revised by* THE DIRECTORS.)

THE headquarters of the Association during the first part of the excursion were at the Castle Hotel, Taunton, and here a considerable number of members assembled on Saturday, July 25th.

On Sunday afternoon Mr. W. Bidgood, the Secretary and Curator of the Somersetshire Archæological and Natural History Society, opened the Society's Museum, and kindly placed himself at the disposal of the members, many of whom took this opportunity of inspecting the valuable collections under his care. It should be noted that this was the first visit of the Association to the districts under review, and that the excursion was favoured by fine weather. The Association was also honoured on this occasion by the presence of that distinguished French geologist, Dr. C. Barrois, who has been a member for many years, and of his friend, Mons. P. Glangeaud, Secretary of the Geological Society of France.

On *Monday, July 27th*, the party went by the 9.45 train to Bridgwater. Here they were met by Mr. Winwood, who acted as Director for the day, Dr. Hicks, and several other members, and were joined by a contingent from the Bridgwater Field Club. From the station they drove through Bridgwater to Cannington, and walked up to the limestone quarry at Cannington Park. The Director having explained the different views that have been held concerning the age of this limestone,* the members proceeded to search for fossils, and many specimens of Corals and Brachiopods were obtained; but their state of preservation was not, in most cases, such as to throw any new light on this vexed question. Attention was, however, called by Mr. H. Corder, of the Bridgwater Field Club, to an exposure of undoubted Devonian rocks lying between the quarry and the village, which is itself on the New Red. The drive was then continued westward, with the beautiful, well-wooded range of the Quantocks on the left. The first halt was at the quarry in Devonian limestone, at Adscombe (p. 380), where some fine specimens of *Cyathophyllum* were procured from a block of limestone lying at the entrance to the quarry, in which *Favosites reticulatus*, Crinoid stems, and a *Stromatoporoid* were also found. A visit was also paid to the quarry in Volcanic Ash in the grounds of Quantock Lodge, a local guide having been obtained, who put the distance first at a quarter of a mile, and then at ten minutes walk. It, however, took much nearer half-an-hour to reach the quarry, which proved to be in a green-coloured ash with a dip to the N.E.† Returning to the carriages, the party drove through Nether Stowey, passing the house in which the poet Coleridge lived for some time, to Holford, where a short halt was made for luncheon, and the Devonian grits were inspected in the Woodlands quarry (p. 381). There was no time to visit the Lias section at Kilve, so the journey was continued through Putsham to St. Audries, only stopping for a few moments to

* See "Notes on the Trias, Rhætic, and Lias of West Somerset," by Rev. H. H. Winwood, M.A., F.G.S., *Proc. Geol Assoc.* vol. xiv, p. 378 (at p. 380). The references in the text throughout this account (except those to Plates XV, XVI, and XVII) are to this paper, or to that on "The Palæozoic Rocks of West Somerset and North Devon," by Henry Hicks, M.D., F.R.S., P.G.S., *loc. cit.*, p. 357.

† A thin section of this rock shows it to be composed of fragments of a green pumiceous glass, very little devitrified.—A. M. Davies.

examine the Devonian section at the Perry quarry (p. 381). Sir A. Acland-Hood had kindly given permission to the party to drive through his beautiful deer-park at St. Audries, and the members were thus able to descend to the shore by the private road known as the "Slip." The Director proceeded to point out the features of the splendid coast section of Keuper Marls, Rhætic, and Lower Lias to be seen from this spot (pp. 381 and 383, and Fig. 2, p. 382), after which the reefs and fallen blocks on the shore were searched for Rhætic and Lower Lias fossils, though, unfortunately, the shore was not in a very good state for collecting, and the time at the disposal of the party was somewhat short. The bone-bed was, however, found, and some of the characteristic fossils of the Lower Lias and Rhætic were obtained, including *Am. planorbis*, *Cardinia*, *Avicula contorta*, *Pullastra arenicola*, *Pecten Valoniensis*, *Pleurophorus*, *Acrodus*, *Ceratodus*, *Gyrolepis*, *Hybodus*, *Saurichthys*. The carriages were then resumed as far as Williton Station, which was reached in time for tea before leaving for Taunton by the 7.19 train.

On *Tuesday, July 28th*, a start was made by train at 8 o'clock for Williton, with Mr. Winwood again acting as Director. On arrival two quarries were visited to the south of the town, known as the Tower Hill and Wyndham quarries. The Keuper sandstones are here quarried for building stone, and with them are associated beds of coarse conglomerate (p. 384). Proceeding to Sampford Brett, and crossing the railway, a very fine section of conglomerate is seen with a finer breccia bed above. This belongs to the base of the Keuper, and as the beds dip rapidly towards the railway, the beds of coarse conglomerate are repeated in the cutting below (p. 384). Returning to Williton, the party took the 12.4 train to Blue Anchor, where they were again joined by a number of members of the Bridgwater Field Club. They then walked by the shore to Watchet, collecting from the Rhætic reefs or the fallen blocks of Lias as they went, and having the chief features of this fine, but somewhat difficult, section (pp. 384 to 387, and Fig. 3, p. 386) pointed out to them, and explained from time to time by the Director. The beautiful beds of pink and white gypsum at Blue Anchor Point, with their curious interlacing veins, were much admired, and further on a diligent search was made, but without success, for a second example of a tooth of the mammal, *Microlestes (Hypsiprymnopsis) Rhæticus*, discovered here by Professor Boyd Dawkins * more than thirty years ago. Among the fossils obtained from the Rhætic beds were, *Pecten Valoniensis*, *Cardium Rhæticum*, *Pullastra arenicola*, *Pleurophorus elongatus*, *P. angulatus*, *Modiola minima*, *Gervillia præcursor*, and teeth or scales of *Saurichthys*, *Acrodus*, *Hybodus*, *Gyrolepis*, *Lepidotus* (?) and from the Lias *Ammonites planorbis*, *Am. Johnstoni*, *Am. semicostatus*, *Am. Bucklandi*, *Gryphæa*, etc.,

* *Quart. Journ. Geol. Soc.*, vol. xx. p. 396.

and some Saurian bones. Nearer Watchet the curious faulting of the Keuper Marls was noticed (p. 385), and on arrival at the harbour, the party left the beach and made their way to the station in time for the 5.13 train to Taunton.

On *Wednesday, July 29th*, a visit was paid to the museum of the Somerset Archæological and Natural History Society, where Mr. Bidgood, the curator, was in waiting to receive the party. Additional interest attaches to the museum by the fact that it is housed in the old castle of Taunton, which is still in excellent preservation. The members were chiefly interested in the collections of local fossils and minerals, particularly in those from the district visited by the Association during the two previous days, including specimens from Cannington Park, the Devonian of the Quantocks, and the Lias and Rhætic of Watchet and St. Audries. There is also a good collection from the Greensand of Blackdown. The great geological treasure of the museum, however, is the case containing the Pleistocene remains excavated from the floors of the Banwell, Bleadon, and other caves in the Mendips. After the President had thanked Mr. Bidgood personally, and requested him to convey the thanks of the Association to the Society, the members made their way to the station, and the 11.5 train was taken for Barnstaple.

On arrival the luggage was taken to the Royal Fortescue Hotel, the headquarters for the rest of the week, and the rain which had been falling during the morning having stopped, the party, under the direction of Mr. J. G. Hamling, proceeded, mostly on foot, but some in carriages, to Codden Hill, a considerable elevation about three miles south of the town. This is situated on the Lower Culm Measures, and the beds here have lately had a new light thrown upon them by the discovery by Dr. G. J. Hinde and Mr. Howard Fox* that the cherts and shales of which they are composed are filled with, and to a large extent made up of, the remains of radiolaria (pp. 367 and 368) ; a discovery which has revolutionised previous theories as to the conditions of deposit of these beds, it being now established that so far from being of shallow water origin, these Codden Hill Beds are actually the "deep-water representatives of the shallower-formed calcareous deposits to the north of them."† Codden Hill quarry was first visited, where the characteristic chert beds were seen, and specimens of the shale, in which radiolaria could be detected with the lens, were obtained in plenty. Here also some examples of *Goniatites* were met with. Overton quarry was the next, and the hill was then ascended for the sake of the view, which includes Dartmoor, Exmoor, and Lundy Island, but was unluckily somewhat obscured. Coming down to Coombe Wood quarry, in which

* *Quart. Journ. Geol. Soc.*, vol. li, p. 609.
† *Loc. cit.*, p. 662.

A.—FOLDED BEDS, WILD PEAR BEACH.
(*From a photograph by* H. PRESTON, F.G.S.)

B.—FOLDED BEDS, HOTEL CLIFF, ILFRACOMBE.
(*From a photograph by* H. PRESTON, F.G.S.)

To face p. 437.

were found *Phillipsia Cliffordi*, *Goniatites*, and Crinoidal stems, the route home was taken by Hannaford and Venn quarries, the former still in the Codden Hill Beds and the latter in the underlying limestones and shales. At Hannaford, *Phillipsia*, *Productus concentricus*, *Chonetes rectispina*, *Athyris*, and *Goniatites* occurred, while in the shales at Venn *Posidonomya* was found in abundance. The evening was spent in a very enjoyable manner at a conversazione, to which the Directors of the North Devon Athenæum had kindly invited the members of the Association. The small but very excellent museum of local geology at the Athenæum was much appreciated, containing as it does a great series of North Devon fossils collected by Mr. Townshend M. Hall.

On *Thursday*, *July* 30*th*, with Dr. Hicks and Mr. Hamling as Directors, the party went by the 8.39 train to Ilfracombe. From the station they drove southwards towards Great Shelfin, Dr. Hicks stopping the carriages at intervals to point out the physical features of the district, particularly calling attention to the view of the "Tors" (Figs. 3 and 4, p. 363). He explained that the appearance of dip-slope and escarpment which these ridges assume was due to the combined results of folds and fractures parallel with the lines of bedding (p. 364). At the cemetery the members got out, and, descending into the valley, they climbed the opposite ridge to the Shelfin quarry. Here, as Dr. Hicks explained, they were on the Morte Slates (p. 359), and a busy search for fossils began. *Lingula Mortensis* was found to be tolerably abundant, as were certain curious organic remains bearing some resemblance to graptolites. In returning to the road a wasps' nest was disturbed, and several of the members were badly stung. Mullacott quarry, on the other side of the road, was also examined, and *Lingula Mortensis* was again found, but the quarry was hardly in a condition to repay research, as it had apparently become the receptacle of all the pots and pans of the neighbourhood. Owing to the great fire in Ilfracombe on Tuesday night, it was impossible to drive through the town and by the coast to Combe Martin, as had been intended, so the route by Berry Down was taken, which meant a loss of time and a consequent curtailment of the programme towards the end of the day. As, however, the road lay along Morte Slates nearly all the way, it enabled Dr. Hicks to point out the contrast of the long even ridge of this old formation with the broken and irregular beds of the Ilfracombe series to the north.

After luncheon at Combe Martin most of the members followed the Directors to the slopes of the Little Hangman, and the more energetic descended with Mr. Hamling to Wild Pear Beach. Here they saw the intense folding of the Hangman Grits (see Plate XV, A.), but were not successful in finding any fossils worth preserving. Those who remained above were able to get some

specimens of the Hangman Grit. Returning to Combe Martin, Dr. Hicks took them to the rocks on the east side of the little bay, and some very clear examples of folding were seen, which convinced many who were previously inclined to be somewhat sceptical on this point. The return was made to Ilfracombe by the coast road, but as time was getting on, only one stop was made, at Hagginton quarry, above Hagginton Beach, where some heaps of limestone and grit yielded abundance of fossils, including *Strophomena rhomboidalis*, *Spirifera disjuncta*, and *Atrypa desquamata*, but in a very bad state of preservation. Owing to the fire, the beach at Ilfracombe had to be gained by a very circuitous route, and there was only just time for Dr. Hicks to indicate a few of the points of interest, including some further examples of folding, of which two of the best examples are represented in Plates XV, B., and XVI, before a move had to be made for the station, whence the return to Barnstaple was made by the 6.10 train.

On *Friday*, *July* 31*st*, the 8.39 train was taken for Morthoe Station, Dr. Hicks and Mr. Hamling again being Directors. Carriages were taken to Woolacombe, and the party proceeded to Barricane Beach, and began to hunt here and in the adjoining coves for fossils in the Morte Slates, but only a few imperfect specimens were found. It was at Woolacombe, near Barricane Beach, that Dr. Hicks first established the fossiliferous character of these slates. Dr. Hicks here gave a short account of the controversy that had arisen over the Devonian rocks, when Jukes wrote his famous paper,* and of the subsequent history of the question up to and including his own announcement of the discovery of fossils in the Morte Slates, a discovery which, taken together with the stratigraphical evidence, in his judgment, proved them to be older than any of the Devonian rocks to the north and south of them, instead of being at the top of the series as Jukes suggested, or in the middle in regular sequence with the beds north and south as Mr. Etheridge and the officers of the Geological Survey would have us believe. He agreed with Jukes in thinking the Morte Slates were separated from the Pickwell Down Sandstones to the south by a great fault, but he went further and held that there was another great fault separating the Morte beds from the Ilfracombe series to the north. He believed that the Morte beds in this area were mainly of Upper Silurian (probably Wenlock) age, and that they had been thrust up in the middle of the Devonian sequence, throwing off the beds on each side (pp. 359 and 369).

Time did not admit of walking to the end of Morte Point, nor of visiting the sandstone quarry in Pickwell Down, which could be seen above the Woolacombe Hotel; so the party now divided, the more active members following Mr. Hamling in a brisk walk

* *Quart. Journ. Geol. Soc.*, vol. xxii, p. 320.

FOLDED BEDS, LANTERN HILL, ILFRACOMBE.
(*From a photograph by* H PRESTON, F.G.S.)

A.—SYNCLINE, PILTON BEDS, CROYDE BAY.
(*From a photograph by* H. PRESTON, F.G.S.)

B.—RAISED BEACH, NEAR SAUNTON.
(*From a photograph by* H. PRESTON, F.G.S.)

To face p. 439.

along Woolacombe sands, at the end of which, after noticing a small outcrop of Pickwell Down Sandstone, they ascended the cliff, and after a scramble over many stone walls reached the end of Baggy Point (p. 366). Here some small quarries in the Baggy Beds (Sandstone) yielded *Cucullæa unilateralis*, *Bellerophon subglobatus*, *Naticopsis*, and other fossils. The coast was then followed round into Croyde Bay, and a descent was made to the shore at a spot where the surface of the slaty rocks is covered with specimens of *Rhynchonella pleurodon*, *R. laticosta*, etc. These occur in the lowest sub-division of the Pilton series, known as the Croyde Beds. Here the remainder of the party was met, they having driven by the inland road to Croyde under the charge of Dr. Hicks. Near this point the well-known "head" or rubble drift sets in, and two large boulders were noticed resting on the Pilton Beds. The larger one measured 6 ft. 6 in. by 4 ft., while the length was more than 10 ft., the remainder being still embedded in the drift. Mr. Hamling thought these blocks were portions of grit from the Baggy Beds. On the other side of the bay Dr. Hicks drew attention to the change in the dip of the Devonian rocks to the northward, an indication of the folding they had undergone; and a little further on some beautiful examples of this folding were seen (see Plate XVII, A.). Climbing over the south point of Croyde Bay, a descent was again made to the shore near Saunton to examine the so-called raised beach.* This consists of coarse sands firmly concreted into almost a hard rock in places, horizontally stratified, and resting on the upturned edges of the Pilton Beds (see Plate XVII, B.). The sands are capped by a deposit of the rubble drift, and they contain numerous pebbles and remains of shells, and are frequently false-bedded. At the very base of the sands, resting immediately on the Devonian, is a large block of red granite,† the point of origin of which is still a problem for geologists. Sir J. Prestwich considered these drifts and beaches to belong to the latest phase of the glacial period. The party then ascended to the Saunton Hotel for tea, and drove to Braunton Station in time for the 6.33 train to Barnstaple. In the evening, after dinner, there were the usual speeches and votes of thanks to the Directors and others who had assisted the Association during the excursion.

On *Saturday, August 1st*, the party started from the hotel in carriages at 9.30, Dr. Hicks and Mr. Hamling directing as before, and drove through Pilton to the quarry known as "Top Orchard," one of the best localities for Pilton fossils. These

* See "The Raised Beaches and 'Head' or Rubble-drift of the South of England, etc.," by Sir Joseph Prestwich, F.R.S., *Quart. Journ. Geol. Soc.*, vol. xlviii, pp. 284 and 285, and Fig. 9.

† The examination of a thin section of this granite shows it to consist chiefly of Quartz and Microcline, the latter mineral abundantly cut across by veins of quartz-mosaic. There is also another felspar present, which is crowded with crystalline enclosures, and biotite occurs in nests here and there.—A. M. DAVIES.

occur in abundance in the limestones, flaggy sandstones, and slates, and the services of Mr. Whidborne in naming the specimens found were called for on all sides, services readily given at all the Devonian sections on this and the two previous days, for which the members are much indebted to him. Among the fossils found were: *Strophalosia productoides*, *Productus prælongus*, *Rhynchonella pleurodon*, *Spirifera disjuncta*, *Streptorhynchus crenistria*, *Chonetes Hardrensis*, *Phacops latifrons*, *Fenestella*, Crinoid stems, etc. The drive was then continued to the Sloly quarry, which is in Baggy Beds, consisting of sandstones and shales. Much fossil wood is to be seen here, especially in one layer of sandstone, and *Lingula squamiformis* and *Cucullæa unilateralis* were met with in some abundance. The chief find, however, was a fine specimen of the phyllopod crustacean, *Echinocaris Whidbornei*, with an impression of another on the same slab. This was found by Mr. Coomara Swamy, and soon afterwards Mrs. Davies was so fortunate as to pick up the other half of the slab. Both specimens were borrowed by Mr. Whidborne with a view to their possible reappearance in the Palæontographical Society's Memoirs. A return was now made to Barnstaple, in order that those who were travelling by the South Western Railway might catch the 2.26 train. The others started on another drive to see a section in Pilton Beds near Chilpham, where the road is crossed by the new railway in course of construction between Lynton and Barnstaple. The beds in this section showed intense crushing and folding. Crinoid stems were abundant, but not many other fossils were obtained. On the way the "Snapper" quarry, near Goodleigh, was examined, also in Pilton Beds, and proved very fossiliferous, *Spirifera disjuncta*, *Strophalosia productoides*, etc., being found. As rain was threatening, the order to return was given, and the proceedings of a very successful excursion came to an end at the Great Western station, when the homeward contingent left by the 4.10 train. Many, however, stayed on at Barnstaple or Ilfracombe, visiting Lynton and other places which it had been impossible to include in the programme, and one small party spent a most instructive three days with Dr. Hicks, investigating some of the difficult problems of the Devonian beds in West Somerset.

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